TeMA

Journal of Land Use, Mobility and Environment

This Special Issue of TeMA - Journal of Land Use, Mobility and Environment, collects ten contributes that deals with emergency planning conceived as a component of the city and territory management process. The focus especially refers to the need of integrating emergency plans and land use proposing a relevant line of research for the mitigation of risks that affect human settlements at different scales.

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The Emergency Plan for the use and management of the territory

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THE EMERGENCY PLAN FOR THE USE AND MANAGEMENT OF THE TERRITORY

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The cover image is a photo of the landslide that hit the municipality of Amalfi (Italy) in February 2021.

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TeMA Journal of
Land Use, Mobility and Environment

EDITORIAL PREFACE

Special Issue 1.2021

The emergency plan for the use and management of the territory

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The issue of emergency planning in areas exposed to natural hazards cannot be yet considered as a focus within the scientific literature, probably because it has been judged as "too operative" for the interest of academic research. The topic of land use planning, spatial planning, and urban planning in risky areas, conversely, has gained attention in recent years. Nevertheless, the examples of good practices that involve ordinary master plans embedding mitigation concerns are still limited. Generally speaking, it is possible to observe that most planners and urban developers, till now, seem to be unaware of the importance that the locational decisions have on defining the exposure and vulnerability to hazard of urban systems. The Emergency Management as discipline, again, can be considered relatively new if referred to the exigence to look for different approaches, based on the definition of mitigation actions and policies, thought as one of the possibilities to face the risks that can occur inside a territory or a city (Bullock et al., 2017). The need of integrating the exigencies of emergency conditions with the contribution of the land use discipline seems to be the meeting point of the recent research concerning risk management. At the same time, this integration is still not actualized but just touched upon in civil protection documents in some countries (such as Australia, New Zealand, Canada). This lack is much more evident when it refers to the operative level, in which the examples of the integration between the emergency plans and the land use plans are very rare. It is also necessary to underline how the issues of risk management are truly close to the concept of territorial and social sustainability and much more of resilience as the capacity to face the emergence at social as well as at territorial level (Molavi, 2018). In this regard, at the international level, great attention is posed to the definition of strategies and actions aimed at the implementation of the disaster risk reduction (DRR) also to define the real responsibilities in preventing and reducing disaster risk as well as to equip states and communities with the tools they need to prevent the creation of new risks. This also depends on the present global pandemic emergency that, if it would have been needed, has shown the fragility of the present economic, social, and territorial organization. The recent Sendai Framework for Disaster Risk Reduction 2015-2030, adopted by the Third UN World Conference on Disaster Risk Reduction in 2015, for instance, ensuring the continuity with the previous documents (International Strategy for Disaster Reduction of 1999, the Yokohama Strategy for a Safer World of 1994, and the International Framework of Action for the International Decade for Natural Disaster Reduction of 1989), introduces some innovative elements and aspects mainly focussing on the awareness that disaster risk management is not to be considered a "sector" in itself, but a practice to be applied across sectors. The Sendai Framework, thus, puts forward a disaster risk management paradigm also based on integration, proposing, among its guiding principles the coherence of disaster risk reduction and sustainable development policies, plans, practices, and mechanisms, across different sectors. The efforts within policies at the global level also concern the will of joining the targets of the disaster risk reductions expressed in the Sendai Framework with the focuses of the 2030 Agenda for Sustainable Development, to improve resilience. Particularly involved in this target are the *SDG 1*: End poverty in all its forms everywhere, *SDG 11*: Make cities and human settlements inclusive, safe, resilient, and sustainable, and *SDG 13*: Take urgent action to combat climate change and its impacts. In the Disaster resilience Scorecard for cities elaborated in 2017 by the United Nations Office for Disaster Risk Reduction (UNDRR) ten *Essentials* for making cities resilient have been pointed out. The Ten Essentials refer to three macro-categories of issues that cities have to address to become disaster-resilient: a) governance and financial capacity; b) the many dimensions of planning and disaster preparation; c) the disaster response itself and post-event recovery. Basing on the concept of resilience meant as the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its Essential basic structures and functions through risk management, the Scorecard insists on the need both of integration between approaches for the risk reduction and of collaboration between the several actors that operate within the urban and territorial systems at different levels (decisional, operative, political, ownership, stakeholders, investors, residents, academia, and so on); these ranges of actors have roles to play in maintaining and improving city resilience. What links resilience and risk management, thus, is, on one hand, the awareness essentially by the residents and people who live and use the city, on the other hand, the process of urbanization and planning as the physical secure basis for making a city resilience to disasters. Another aspect that must be underlined concerns the prevention of the risks for communities and decision-makers. The debate about the importance of the prevention for the reduction of the negative impacts due to hazards natural as well as anthropical is still thought-provoking both the academic environment and the political level. The theme is still difficult to address, especially for the Italian situation. Italy, in fact, is characterized by a large and diffuse condition of fragility both for its specific geographical morphological features and for its lack of efficient policies aimed at reducing this fragility. In recent years, indeed, also in Italy the theme of prevention has become central even due to the catastrophic seismic events that occurred in Abruzzo in 2009 and then in Central Italy in 2016, as usually for Italy, some regulatory measures have followed (L. 77/2009; D.L. 189/2016; D.L. 205/2016) that have been especially focused on the distribution of economical sources to face the post-emergency phase, normally devoted to the reconstruction. It is meaningful that the Civil Protection Department has been founded in the early Eighties after one of the most relevant catastrophic event for Italy (the Irpinia earthquake) especially if it is referred to the fact that Italy with its concentration of natural risks (volcanic, seismic, hydrogeological, tsunami, fire, climatic) could be a significant practical laboratory for experimenting new approaches, practices, and theories for the prevention, the mitigation, the adaptation and the management of territorial risks, both natural and not. The Recovery Fund, universally recognized as a unique occasion for the reprise from the impacts of the pandemic event of Covid-19, is the forthcoming challenge for Italy in the sense of being able of planning resources for a real transition towards resilience and sustainability. In the framework of these considerations, this special issue of TeMA Journal of Land Use, Mobility and Environment proposes to point out the topic of the emergency plan for the territorial management and use, trying to underline the need of making these tools more dynamic and appropriate to the exigencies of territory meant as dynamical and complex systems. To this end, this special issue collects and compares the opinions of researchers and technicians around the complicated topic of natural and anthropic risks to contribute to the planning of the management of risks. The basic idea in proposing this Special Issue, in fact, born from the need to analyze the effects caused by natural and anthropic risks, without leaving reactions and answers to the territorial systems' spontaneity (Holling, 1973; Colucci, 2012; Bettini, 2014), while it is necessary to guide and direct these responses (Jabareen, 2012). To achieve more effective results to promote resilient processes of territorial systems, several strategies could be pursued: thinking of new plans and/or programs capable of offering precise and targeted guidelines; reconsidering some plans and/or programs already present. It also aspires to be a useful opportunity to reorganize some operational or territorial management plans in a more "resilient" way, preparing them to deal with the crisis from different points of view (structural, ecological, social, and economic), interlacing specific issues of risk mitigation with those of territorial planning. Moreover, considering that the state of the art for many years now has intertwined issues of risk mitigation with those of territorial planning, this special issue aims to investigate useful approaches to enriching in terms of space and operational plan such as the emergency plan. These plans are the operational plans of the rescue forces. They are the plans in which all the activities and procedures that must be adopted to face a calamitous event expected in a given territory are mainly coordinated, to guarantee the effective and immediate use of the resources necessary to overcome the emergency and the return to normal living conditions (Lindell, 2013). Over the years, the legislative instruments supporting the strengthening of the Civil Protection bodies have paid more attention to forecasting and prevention activities rather than just managing events that occurred. Consequently, this has led us to consider the planning and management of emergencies not as separate processes, but rather as closely related and interdependent, inserted in a wider cyclical process that also includes the phases of mitigation and restoration of normality. The emergency plan, therefore, can be considered the ideal operational plan to pursue risk mitigation strategies, also aimed at favoring the pursuit of the customer status of specific territorial contexts. This above all if it is increased in terms of defining optimal solutions for areas at greater risk and with complex management problems. It is therefore opportune to assign emergency plans a more articulate and dynamic sense, especially in terms of connection with the discipline of land uses and assets. With this aim, the special issue embraces the most recent research developments that pursue a planning/design using a more holistic approach. Based on the contributions of scholars coming from different disciplinary backgrounds, this number of TeMA allows for defining the state of the art about the need to manage and address the different hazards that can occur. In detail, the first paper *Water-related risk reduction in urban development plans. Recommendations for resilient planning practices from a Sicilian case study investigation* deals with the complex relationships existing between land use planning and disaster risk reduction focusing on water-related risks. The paper aims at exploring and defining a set of proposals for increasing the effectiveness of actions taken by local administrations, at the stage of drafting and implementing local land use masterplans, so to enhance all aspects of disaster risk reduction in the planning practice. The second paper *Evaluation vs Landscape Planning in the Italian framework. Is risk prevention a utopia?* concerns the question of whether landscape planning is able or not to prevent and protect against the risks deriving from poor management of the territory. The author wonders about the role of the planning tool in the protection of the territory and the landscape underlining the lack of planning activities, both at general and sectoral levels. The definition and experimentation of a particular model of basic Knowledge System is the focus of the third paper - *Spatial knowledge for risk prevention and mitigation. The civil protection planning of the Abruzzo Region* - in which authors describe the result of a research concerning the theme of Civil Protection Planning at Regional level and Disaster Risk Management. An original analytical methodology of the Knowledge System has become the basis for the experimentation of a Regional Management Risk Plan (case study Abruzzo Region), a part of the Regional Civil Protection Plan, which allows identifying the Hotspots, i.e. areas characterized by very high and probably simultaneous risks, in which it is strictly necessary to identify prevention and mitigation interventions, the 'Territorial Prevention and Recovery Projects' that concern the structural activities of civil protection. The rural areas are the focus of the fourth paper *Climate change as a stressor in rural areas. Vulnerability assessment on the agricultural sector* in which authors define a methodology to quantitatively assess the level of vulnerability to climate change based on climatic and context analysis at the municipality scale, particularly referring to rural areas. The methodology is based on numerical and statistical computation operations on a set of indices of climate exposure, sensitivity and adaptive capacity to provide an aggregate Vulnerability Index. The paper presents the results of the application to the Calabrian territorial context of the Grecanica Area (Italy). In the fifth paper *Emergency and spatial planning towards cooperative approaches Challenges and opportunities in the multi-risk area of Campi Flegrei,* authors focus on a specific area of Campania intending to highlight both the main criticalities of the emergency plans recently carried out for the selected Municipalities and the difficulties and opportunities related to better integration between spatial and emergency planning at the municipal scale. The theme of risks connected to the presence of dams has been pointed out in the sixth paper *Territorial aspects of Emergency Plans for Dams.* Based on a recent experience carried out within a collaboration framework with the Lombardia Region, the paper provides indications on the current problems and opportunities related to risk management, emergency preparedness and planning in presence of dams considering technical, social and public policies decision-making issues as key. The paper also proposes initial reference to the national and international experience on the topic to discuss more in-depth how territorial aspects have contributed substantially to shape emergency plans for dams and what are the consequent impacts on ordinary urban and regional plans at different scales. In the seventh paper - *Assessing the potential of green infrastructure to mitigate the hydro-geological hazard. Evidence-based policy suggestions from a Sardinian study area* - authors propose a better understanding of the role that could be played by green infrastructures (GI) as regards hydro-geological hazard is gained, and policy recommendations aimed at mitigating the associated risks are identified. A methodological framework is defined to assess the relations between GI and hydro-geological hazard through inferential analysis based on dichotomous-choice Logit models, under the assumption that the implementation of GI within planning policies could enhance environmental protection and people's wellbeing. The eighth paper *Environmental quality of emergency areas. A methodology to assess shelter areas liveability* presents the first results of a research aimed at identifying and assessing the factors useful to ensure an adequate environmental quality of the shelter areas, defined following the comparative study of evaluation systems used in different countries. In this paper, the authors underline the goal of the research to provide the opportunity for a broader reflection on the relationship that needs to be established between these evaluation systems and planning tools, in respect of which there is at present almost total independence. In the ninth paper *Fostering Holistic natural risk Resilience in Spatial Planning. Earthquake Events, Cultural Heritage and Communities* the authors propose to build a framework of knowledge to integrate perspectives of natural risk resilience (natural risk, cultural heritage, communities, spatial resources, and spatial planning) tested on research cases in areas affected by earthquakes in Italy and Croatia. The Heritage Urbanism approach is applied by comparing the Central Italy disaster and trends in the Croatian capital of Zagreb, providing identity factors and evaluation criteria to assist in reading existing resilience models and building new models. Structures to interrelate aspects of (land/urban) scape resilience and models of natural risk resilience contribute to enhancing risk reduction and resilience in urban planning in high-risk situations. In the paper *The Time Profile of Transformations in Territorial Governance. Towards a Meeting Point between Urban Planning and Risk Management author* mainly refers to a difficult balance between spatial and temporal projections in plans. The author highlights how this unequal development in planning contents, territorial governance has shown a worrying loss of authority, which tends to generate evident contradictions when territorial planning is called to contend with problems deriving from the management of areas where urban planning forecasts must coexist with extraordinary provisions adopted following an earthquake or other natural disaster. He also draws attention to the present transition period in which convergence of interests is needed not only in those areas cyclically affected by calamitous phenomena but also in territories preparing to host the most significant interventions of the PNRR that seem destined to undergo the next phase of intense transformations relying on the culture and tools of strategic planning. In the eleventh paper *Planning to prevent disasters. A short reflection on the correlation between ordinary planning and risk mitigation,* the author with methodological intent, tries to investigate how risk can be better understood and how town planning may influence its mitigation. In a conclusion, the author draws attention to the need for a change of attitude: to get out of the logic of the emergency, outlining the possibility to transpose the emergency into the administrative and decision-making processes in this helping in bringing out a civic awareness of the value of the common goods. The response to the call of this special issue suggests making some conclusive reflections about the issue of the emergency plans and in general about the engagement of the territorial planning for the improvement of their resilience. The contributions to the Special Issue have shown a quite unanimous convergence towards the awareness that policies, as well as the techniques, cannot more act according to sectorial and separate vision, a holistic approach, instead, has to be implemented to respect the complexity of territory and cities as systems.

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Water-related risk reduction in urban development plans

Recommendations for resilient planning practices from a Sicilian case study investigation

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Abstract

The goal to create hazard-resilient communities through sustainable land-use planning requires a fundamental change to the way in which planning is conceptualized and practiced. This implies a deep revision of the operationalizing policy and legislation at local levels and a clearer interpretation of the in-between domain of risk and emergency assessment and management. This study deals with the complex relation existing between land use planning and disaster risk reduction and focuses on water-related risks. It aims to explore and define a set of proposals for increasing the effectiveness of actions taken by local administrations, at the stage of drafting and implementing local land use masterplans, so to enhance all aspects of disaster risk reduction in the planning practice. In particular, novel contents for the local urban masterplans are investigated based on a case study located in eastern Sicily, Italy: considerations concern urban key criticalities analysed within the catchment of the Lavinaio-Platani, the latter being one of the most dangerous stream in the considered area. Although focused on a specific context, the outcomes of this research may be relevant for a wider range of urbanized environments, especially if prone to flooding risk, by providing targeted recommendations and cross-sectoral perspectives to profitably inform innovative masterplans.

Keywords

Land use planning; Urban resilience; Water-related risk reduction.

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1. The in-between topic of risk and spatial planning

1.1 Land-use planning as best practice for disaster-risk-management

Disaster risks from extreme natural hazards or man-made sources, result in a process of "risk accumulation" specific to urban areas, where risk is amplified by human activities (UNDP, 2010). The UNDRR report (2020), published to mark the International Day for Disaster Risk Reduction on October 13, 2020, confirms how extreme weather events – among which floods and storms were the most prevalent - have come to dominate the disaster landscape in the 21st century, with the last twenty years having seen the number of major floods more than doubled and the incidence of storms importantly grown. Risk level can be amplified by inappropriate human behaviors such as negligence, weak or bad land use planning and exposure of human settlement to not recognized hazards (Roy & Ferland, 2015). This is particularly true with regard to water-related hazards and urban flood risks (Zhou et al., 2019; Barredo & Engelen, 2010).

At the city scale, an effective opportunity to build resilience and to mitigate risks is given by urban planning: a discipline which deals with the development and the control of land and the management of spatial configuration and activities within urban areas. Planning practice has always been central to public interests and concerned urban areas as scenarios for future change and as the preferential place to adapt to climate change and to mitigate its impact (La Greca, 2017; Barbarossa, 2017). Urban planners have the responsibility to drive communities through a path of risk reduction, allocating safe land use categories and setting proper development plans, identifying and mapping all kind of risks, supporting preparedness and public participation as well as social acceptance, providing geospatial information, land use regulations control and implementation monitoring. Furthermore, suitable land use planning and development plans were identified as priority actions for risks reduction and to contrast the growing number of natural disasters as well as the related deaths and economic costs. (UNISDR, 2007; UNISDR, 2015).

As matter of fact Land Use Planning (LUP) should be considered itself as a Disaster Risk Reduction tool (UNISDR, 2015) that could be exploited by local authorities and communities to reduce risks due to the capability to increase urban resilience and sustainability (Saunders & Kilvington, 2016).

That is in order to implement policies, guidelines, plans and design standards, oriented to integrate disaster risk reduction actions into land tenure and management practices. Despite this potential, most cities are not devoting adequate efforts to handle risk issues and seem not interested or not enough well prepared for a fully implementation and achievement of climate changes adaptation and mitigation and for the implementation of urban plans based on risk reduction.

Notably in Italy, the planning practice mostly shows a limited awareness of risks issues, mainly expressed through few inadequate measures encompassed in city masterplan provisions, rather than strategic approaches to define planning actions (Galderisi, 2020; Menoni, 2020). There is a gap in understanding how DRR themes can be included in urban plans, policy and legislation and what best practices might look like (Hurlimann et al., 2020). Especially in South Italy, the analysis of how risk issues have been addressed in city masterplans, starting from strategic approaches to land use choices and regulatory issues, makes it clear that DRR themes have been seldom effectively included in urban planning process undertaken by local governments, which have rarely considered the risks reduction issue in their urban policies and land use choices in a proper way (Barbarossa et al., 2018). This outdated approach is mainly the consequence of traditional planning practices that have suffered from poor co-ordination and integration between spatial and sectoral decisions caused by the separation existing in practice between urban development plans and other sectorial plans, both at the regional and local scale (Di Giovanni, 2016). The latter is also due to the Italian planning tools that are hierarchically structured on three levels of plans: regional plans, supra-municipal plans and municipal plans that are implemented by different authorities (regional or local) and could be referred to different categories, such as development plans (regional plans, city masterplans, land use zoning plans, detailed plans, etc.), regulatory plans (landscape protection plans, etc.), infrastructures plans (transport, energy, telecommunications, etc), risks plans (emergency plans, geomorphological and hydrogeological plans, etc.).

1.2 Municipal emergency plans and urban development plans

In Italy, issues related to risk assessment and management have been primarily addressed by the Emergency Plan, which is the most relevant instrument containing prescriptions and limitations under a comprehensive strategy for emergency regulated by national laws and guidelines.

At the local scale Mayors are identified as the main authorities of Civil Protection and therefore responsible for the implementation of the Municipal Emergency Plans. These plans are issued following the National Civil Protection Department guidelines and rules, which contain the methodology for defining their contents and for the implementation of projects and activities.

In terms of approval procedures and controls, the same plans present some weakness and result in being partially inadequate to cope effectively with risk management.

As a matter of fact, they mainly deal with the immediate response to emergency, without providing wide-ranging strategies or measures or comprehensive approaches to reduce risks and increase the safety level of the territory. On the contrary, through the analysis of singular risk scenarios that may affect the urban environment, the focus of these plans is very often limited to the emergency management and rescue operations (Menoni, 2020). In particular, the Emergency plans define monitoring activities, intervention models, operational procedures, and areas suitable to allocate operative procedures for a correct emergency management (Galderisi et al., 2020). This kind of planning has proven to be useless several times, especially in case of high disastrous events. Many times, although equipped with specific emergency tools, urban areas were not able to properly face and manage extensive impacts.

Moreover, authors such as Pirlone et al. (2020) highlight that the lack of proper connections between Emergency and Land Use Plans makes the emergency management less effective to achieve territorial safety. Indeed, local governments are directly responsible both for urban development plans and emergency plans.

Considering that both plans are implemented by the same planning authority, the emergency plan should share inputs and provisions with the development plan that aims to promote desirable social and environmental outcomes as well as regulate urban and land functions and manage spatial configuration of the city (Neuvel & Van den Brink, 2010). Those functions should be carried out according to the needs of urban development, while safeguarding natural resources and in respect of site-specific features of the territory (geomorphological, hydrogeological, etc.) and above all, taking into account hazard prone areas and their vulnerability characteristics. Both plans should therefore provide synergic planning measures based on the improvement in processes of risk assessment and management, also taking into account sectoral hierarchical plans (seismic, hydrogeological, etc.) at different scales.

For example, focusing on water-related risks, the assessment and management of floods are among the main topics of the (River Basin) Hydrogeological Plans (PAIs), which are sectoral plans addressed to the assessment of hydrogeological hazards and exposure and to the management of resulting risk, approached at the river basin scale. Currently, these plans are basically included and integrated into the Flood Risk Management Plans (FRMPs), which are the result of the Flood Directive (Directive 2007/60/EC). In Italy the maps prepared by the PAIs, used the same, and sometimes more exhaustive, information required by the preliminary flood risk assessment, including the identification of the areas at significant flood risk. Therefore, Flood Hazard and Risk Maps of the FRMPs, enhanced and integrated the contents of the PAIs, according to the national guidelines provided by the Environmental Ministry of Land and Sea, with the input of ISPRA, River Basin Districts and the technical board State-Regions. The Legislative Decree 49/2010 provides for the FRMPs to be prepared as part of the planning activities of the basin districts and taking into account, among various other aspects, spatial planning and land uses.

1.3 Barriers to an effective integration of DRR actions into urban plans

Unfortunately, the coverage of DRR actions in urban planning and policies, seems to be rather fragmented and disorganized, and often affected by undesirable difficulties associated to data collection, analyses changes of scales, and regulatory issues, or other (Galderisi, 2020). For example, a proper integration of sectorial plans' contents into urban development plans is often affected by typical constraints related to the adjustment of data and results of analyses provided for a larger scale and adapted to the city one, compromising the availability of fundamental information.

In addition, contents of larger scale and sectoral plans could become quickly obsolete due to the long time required by urban development plans' implementation and approval procedures and, above all, for the slowness or inactivity of local administrations in implementing urban plan provisions. At the same time, local short times changes might occur despite minor implementations and land use changes, and this could affect vulnerability exacerbating potential negative.

Other barriers are caused by the fact that urban development plans and emergency plans usually include outcomes coming from different large scale sectorial plans and obtained from different type of hazards investigations. Large-scale plans (supra regional or regional) usually concern a single type of hazard, and rarely assess the possible effects of combined risks (Menoni, 2020). Consequently, those issues are not taken into account also in local plans, whose risk assessment could result largely underestimated.

Finally, large scale sectoral plans, usually provide recommendations and prescriptions about risk reduction but rarely directly impose restrictions on the territory, demanding the regulatory functions to the urban plans, whose planners often meet much difficulties in justifying proper actions and regulatory choices concerning risk mitigation (MacAskill, 2019).

According to Pilone et al. (2016), neither large scale sectoral plans with related legislation, nor local planning tools provide local authorities with adequate means to address high risk situations, especially in cases of incompatibility or coexistence between hazards and urban functions.

All the factors mentioned could potentially undermine contents, scopes and provisions addressed to risk reduction in urban development plans. This matter becomes particularly unfavorable if we consider that municipalities and their planning instruments remain in many cases the only forefront towards the risk management, the prevention and the protection of the population.

To solve these critical issues new integrated approaches for emergency plans and land use plans have been already advocated.

Starting from these considerations, the aim of the present research is to define an effective practical framework for including the risk assessment into urban planning and land use practices and to provide the local government with innovative and specific procedures, design strategies and tools, useful to put in practice an effective DRR approach at the local scale.

In the introduction section above, the paper firstly argued about the complex relation existing between urban and land use planning and disaster risk management, touching upon contents of traditional emergency and sectoral risk management plans and underlining weakness and conflicts of their co-existence and parallel evolution with urban development plans, focusing on water-related risks.

In the following Section n.2, the case study is described along with the methodology used to approach it and results of analyses performed. Section n.3 encloses a broader discussion on the urgent need and related barriers of enabling the Sendai Framework at the local level through land use best practices.

The discussion originates from the case study and the proposed set of potential solutions for the transfer of DRR principles into urban planning and practices. Finally, conclusions are intended to return basic take-home lessons to readers.

2. Novel contents for the local urban Plan: tips for water-related risks reduction from the Sicilian context

2.1 Novel contents for the local urban Plan: tips for water-related risks reduction from the Sicilian context

The Lavinaio – Platani is acknowledged as the most dangerous in the Acireale area, which is located along the east coast of Sicily, fifteen kilometers north of Catania. The stream's natural catchment is about 65 square kilometers with elevation higher than 200 meters on the sea level. The Lavinaio-Platani is about 18 km long and reaches Acireale close to its southern municipal boundary after flowing across rural, urban and peri-urban contexts belonging to several municipalities located on the north - east slopes of Etna mount. The basin is thus a steep and broad area not proportional to the stream hydraulic section at more than one cross sectional area and mostly with regard to its downstream segments in the city of Acireale (Orlando et al., 2014). The watercourse shows different shape configurations with alternation of natural riverbed and artificial open or underground channel cross sections, and flows into the sea passing through one of the small villages built along the coast.

Also known as "the killer" due the several deaths occurred during major damaging floods, the watercourse is mostly classified with the highest hydraulic hazard level by the Sicilian PAI (2018).

Despite the recognized hazardous conditions, local land use plans have never imposed for the flood prone areas clearly stated limitations to the uncontrolled development of farmland nearby to the riverbed, with the result of failing in preventing impacts of flooding occurrence. On the contrary, the process of urban growth characterized by the pervasiveness of the agricultural or fishing activities, which have conditioned for centuries the progressive shaping of the Acireale territory and its local economy, was swiped out by recent processes of low-density urbanization of peri-urban and rural areas speeded up between 1970 and 2000. Urban growth during the last fifty years was governed by inadequate urban plans that did not take into account agricultural land protection and sustainability. These plans produced the new medium and low-density settlements, developed close to the historical villages as well as in rural areas, overwhelming and jeopardizing the fragile rural ecosystem with the loss of landscape values and ecological relevant features.

This unfavorable scenario, has suffered from hydrogeological and hydraulic calamities, very often due to the conflicting compresence of the hydrographic network and the anthropogenic activities.

Both the Civil Protection and the local Civil Engineering Department, which have competences in risk assessment and management at the scale of the entire Province, have repeatedly dealt with the complex challenge of solving the recurring problems of insufficient discharge capacity, local overflows, infrastructure breakdown by means of hydraulic analyses, interventions on the riverbed, engineered channeling and projects for construction of artificial storm-water basins.

Despite the numerous technical interventions, catastrophic events have taken place with dramatic impacts (recently in March 1995, September 2005, October 2006, September 2013), widespread dissatisfaction and indignation of the local community and responsibilities rebounded among politicians, local authority and technical offices representatives. Moreover, the urban development plan currently in force, does not properly consider the hydraulic hazard related to the Lavinaio – Platani. With the exception of the developing constraints for riverbeds, imposed by a national act, the plan does not contemplate any other tool or regulation oriented to cancel or limit the development index for the areas surrounding the stream and prone to flooding. As a consequence, there is no land use provision specifically oriented to risk reduction.

2.2 The case study: a methodological approach

A proper analysis of socio-hydrological territorial dynamics should be extended to the scale of an entire catchment. In fact, strategies for risk management through prevention, protection and preparedness are traditionally assigned to flood risk management plans, which should strategically include also the promotion of sustainable land use practices, nature conservation support and the definitions of all those structural and non-structural measures able to reduce the likelihood of flooding and to prevent from the potential adverse consequences of flooding for human health, the environment, cultural heritage and economic activity.
Similarly, considerations on hydrologic systems landscape values are among contents of Landscape Protection Plans, developed at the large scale.
Otherwise, the development of masterplans is inevitably limited to the area delimited by municipality boundaries. Accordingly, the extension of analyses at the scale of the entire catchment is out of the purpose of this study, which rather focus on the municipal masterplan dimension.
The method used to approach the case study is designed in three phases in order to better understand the dynamics and the co-evolution of the coupled human-water system, focusing in particular on the changing relations between hydrological regimes and the urbanization processes.
The first stage corresponds with an analytical phase.
In order to define a precise area for investigations, the stream buffer area of 300 meters as reported in the regional Landscape Protection Plan was considered together with an enlarged buffer zone of 500 meters.
To analyse the likely conflicting elements of the stream-urban features' coexistence, a spatially explicit, GIS-based approach was applied to map the urban growth process, the mobility system and the current land uses next to the water course. Moreover, all needed information derived from the PAI and the (civil protection) emergency plan were considered for a proper definition of the existing risk scenario.
The first analysis qualitatively detects the stream crossing density and the proximity of roadways to the stream bed. The streets' network is the direct consequence of land development and often by far a greater source of sediment to watercourses than all other land-uses combined. A further analysis evaluates the urban growth process in the last decades by examining and comparing historical and up-to-date cartographic sources and by the means of aerial photographs' interpretation. Patches of developed areas have been identified based on six representative time thresholds of urban growth, namely 1924, 1964, 1985, 1999, 2007 and 2014. This preliminary analysis was performed in order to obtain a qualitative indication on the transformations that the urban growth process has determined in land use modifications and soil sealing progress nearby the watercourse, which is likely to result in deeply influencing the catchment's hydrologic response. Finally, land uses analysis was performed by interpretation of aerial photographs, and defining a proper classification system to distinguish natural and man-made features and so the existing landscape patterns along the Lavinaio-Platani. A range of considerations is provided in the following by describing some specific features that have resulted in being characterizing for the considered stream buffer areas. In fact, the second stage of the methodological approach reads into the results of the performed analyses to recognize and classify key criticalities, for which comparable examples have been also depicted out of the Acireale municipality borders, following the Lavinaio-Platani to its source, thus proving their connotative and recurring occurrence along the watercourse. The last stage correlates the identified key criticalities with a number of planning objectives that should inform the planning process for designing an urban development masterplan very much focused on integrating water-related risk reduction guiding principles through better planning choices, land use and zoning decisions and practices.

2.3 The case study: reading out the results

Fig.1 maps the results of the analyses carried out under the first stage. The stream section crossing Acireale flows through different land use patterns, which range from crop fields, citrus grove and sparsely vegetated areas to commercial-industrial units and medium density continuous residential urban fabrics. Apart from scattered rural buildings and historical centres already existing at the beginning of the twentieth century, the most significant increase in urban development has occurred between the eighties and the early nineties, following unsustainable planning trends which now seem totally foreign to the culture of sustainable development, yet already internationally acknowledged since the nineties.

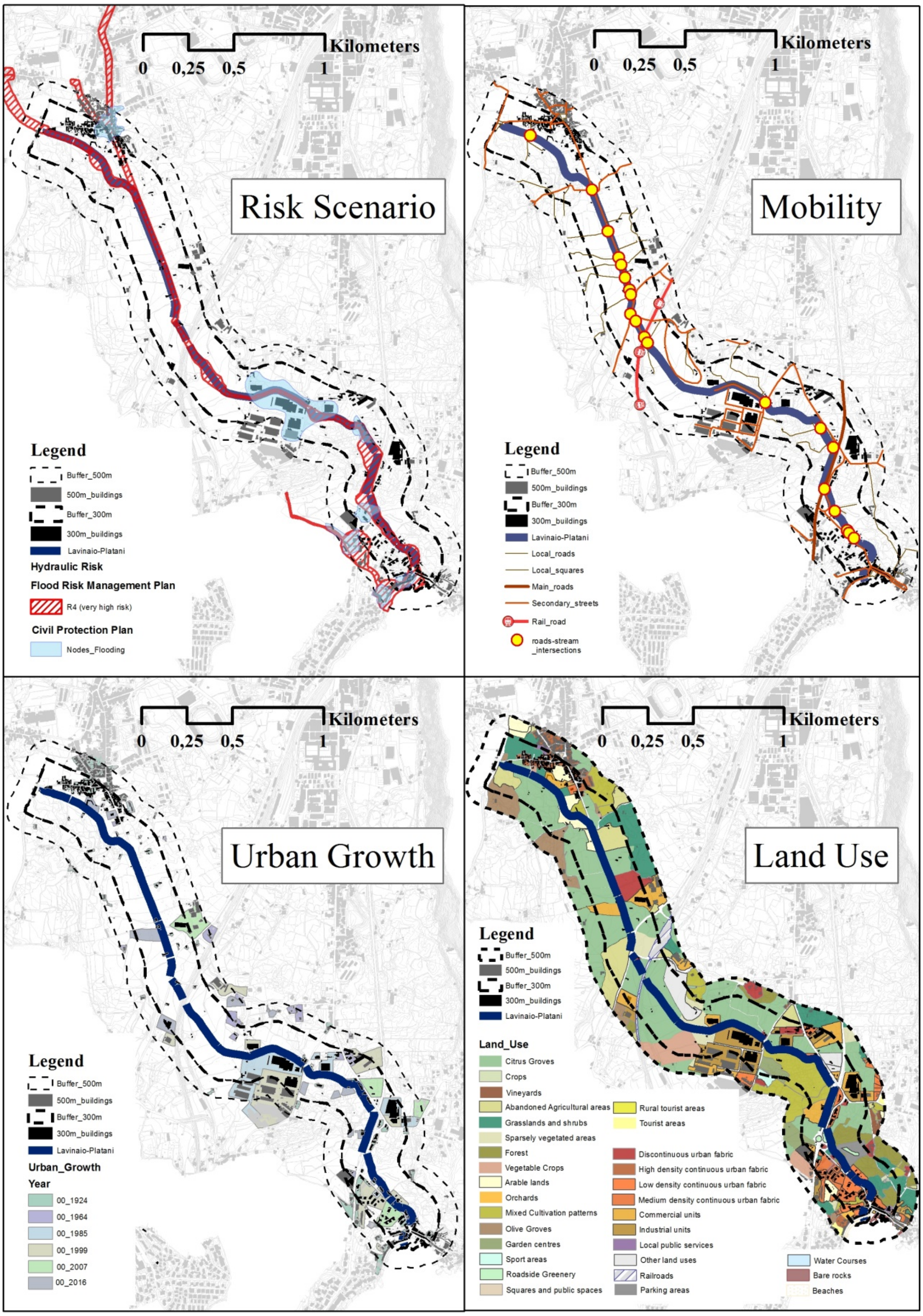

Fig.1 Analyses of "Risk Scenario", "Mobility", "Urban Growth" and "Land Use" next to the Lavinaio-Platani, Acireal

According to the sectoral Risk Management Plans (PAI, 2008; FRMP,2018), a very high level of hydraulic risk outlines the entire section, with some particularly dangerous nodes within the urban areas prone to flooding. Figure 2 presents some other examples of the likely conflicting coexistence of the stream and urban features within the Lavinaio-Platani catchment, upstream of the Acireale municipality.
A first consideration coming out of the two representations is related to "land use practices" that here are intended to include both planned land uses and autonomous usage within the private parcels.
Surprisingly, quite often along the Lavinaio-Platani, from upstream to downstream, a number of new urban micro and macro expansions have progressively grown (Fig.3) and many new buildings close to the riverbed have been built together with floodwalls, constructed close to property boundaries. Moreover, autonomous and not authorized modifications to the stream have been determined by not compatible human uses and activities with the consequence of the original natural floodplain being altered, potentially causing negative impacts on local drainage patterns and the unpredicted transfer of flow rates and volumes in time and space. Over time, localised engineered interventions not supported by a strategic spatial planning approach may have resulted in unpredictable burden caused downstream in terms of soil erosion, higher and more rapid peak discharges and higher runoff volume, the damages to in-stream and streamside habitats as well as co-detriments such as loss of water quality, water resources, amenity and biodiversity.

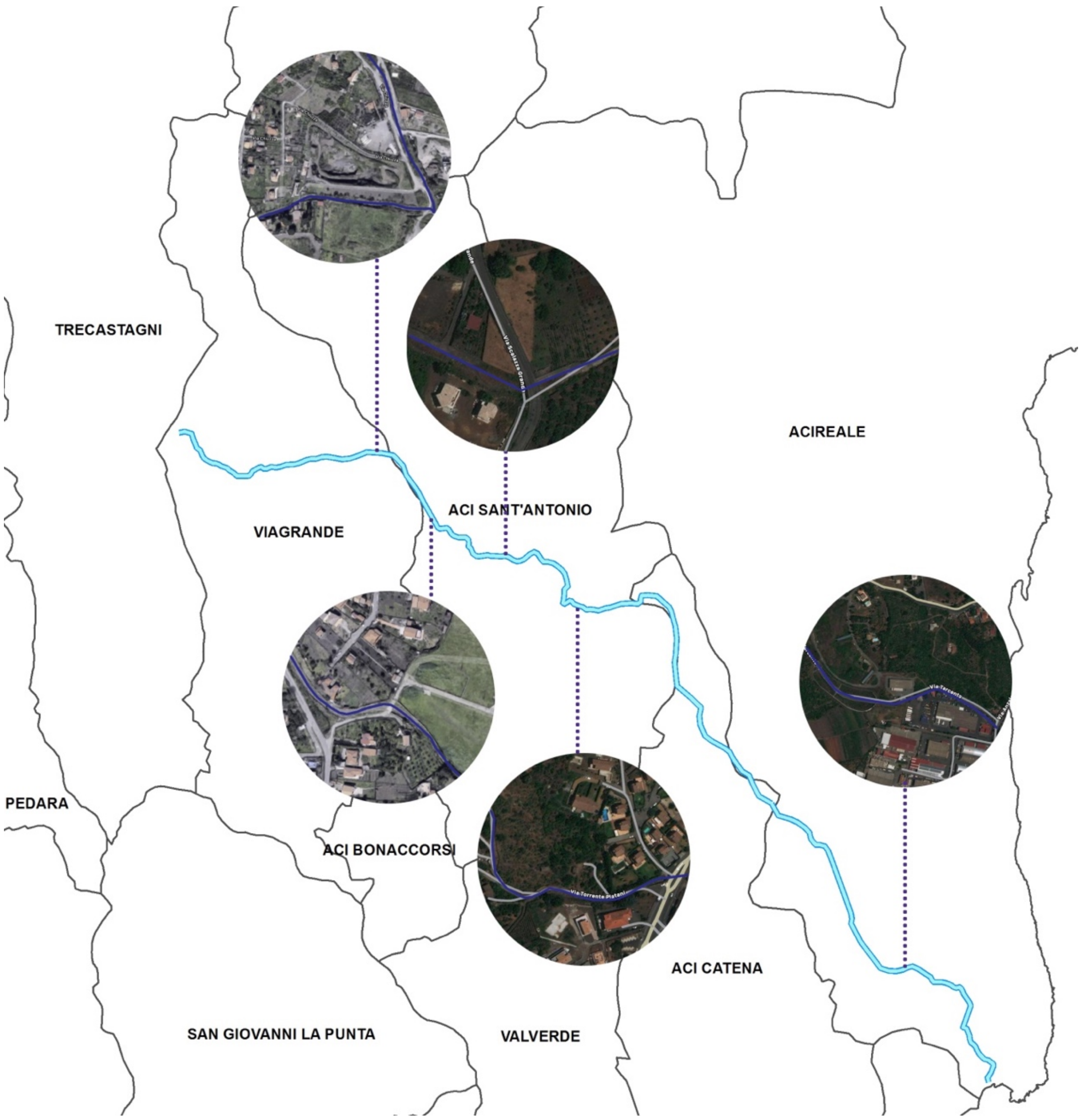

Fig.2 Examples of potentially conflicting coexistence of the stream and urban features within the Lavinaio-Platani catchment

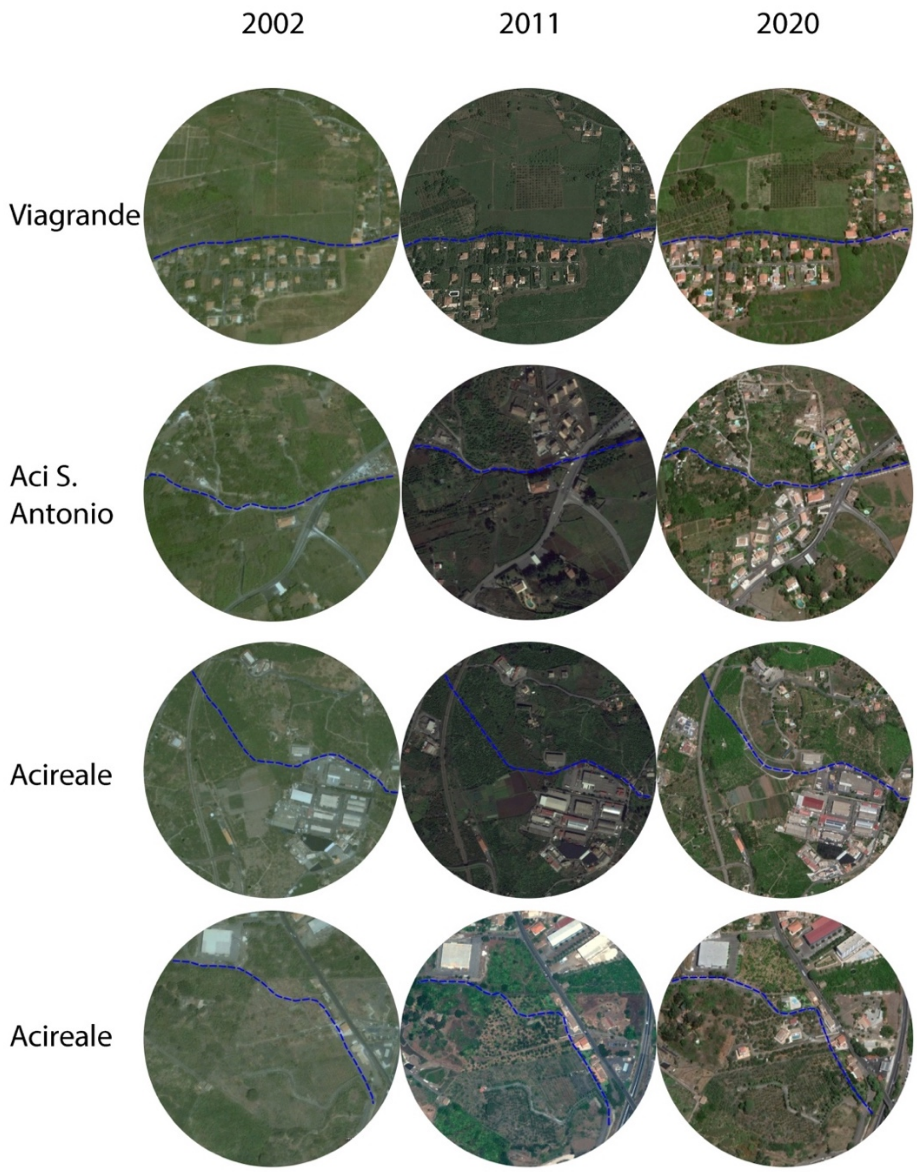

Fig.3 Examples of urban development with land cover modifications within the Lavinaio-Platani catchment

The occurrence of flooding events along the downstream portion of the stream have suggested additional hydraulic work interventions such as those for redirecting the natural stream in an artificially constructed stream bed through channelization, or the recent construction of an important catchement basin in Acireale nearby the railway crossing.

Urbanization processes have been also implicated the development of new local and secondary roads to infrastructure additional urban areas and to serve private properties. These roads have been traced on previous rural paths, which followed the course of the stream and overlapped to the dry riverbed. The numerous intersections between the road system, the private properties' accesses and the water course generate a complex scenario of potential diffused flooding risk. Nowadays, the roads network shapes a disorderly urban pattern, characterized by the loss of ecologic and landscape values, critical nodes of intersection with the stream, paved and altered portions of the bed and modifications of the hydraulic sections. The following categories of key criticalities have been thus identified as especially typifying the case study:

- Conflicting land use practices and urban sprawl;
- Conflicting intersections between the watercourse and the roads network, and in particular: Road/watercourse intersections and stream crossings to access private properties.

Proximity of parallel streambed and roadway or coincidence of streambed and roadway.

The abovementioned points were considered as the reference to set the planning objectives underlying the framework presented in the next section, which is intended as tangible proposal for inspiring better local decisions addressed at the enhancement of the existing conditions, especially in risk prone areas.

3. Novel contents for the local urban Plan: tips for water-related risks reduction from the Sicilian context

3.1 Resilience in practice: setting a framework of potential solutions

The spatial planning and policy transition to alternative storm-water management approach is clearly not yet started.

Indeed, spatial planning trough land use control should be directly related to exposure and vulnerability, but also to water-related hazards, which can be both naturally and anthropogenically driven (White, 2010).

Namely, urban morphology, greenspaces provision and distribution, building and hard infrastructure design, information on flood prone areas and engagement polices of vulnerable groups, do provide rooms for successful risk adaptation (Codemo et al., 2021). At the same time, localized mitigation approaches become possible based on the consideration that water-related hazard depends on rainfall-runoff transformation processes: the interaction between precipitation and surfaces, the latter both natural or manmade, is the key to explore how to lessen the water-related hazard in the city (White, 2010).

Not surprisingly, the green infrastructure (GI) planning and the adoption of Sustainable urban Drainage Systems (SUDS) as components of GI in urban contexts are increasingly being recommended both at the strategic planning level and at the practice stage for addressing a more sustainable management of urban flood risk while providing a wide range of ecosystem benefits (Gimenez-Maranges et al., 2020; Pappalardo and La Rosa, 2020; Alves et al., 2019; Thorne et al., 2018). However, none of current local planning tools refer for example to the use of these nature-based solutions to manage storm-water, or to the principle of hydraulic invariance. The upstream control of runoff volume and flow discharge as well as strategies for collecting and reusing the rainwater, for reducing impervious surfaces, for landscaping and vegetation struggle to enter the urban planning and decision-making domains (O'Donnell et al., 2017).

To partially overcome these limitations, this study presents the framework of Table1, in which risks concerns are integrated with the establishment of new rules, legal restrictions and alternatives ways for using land rights on hazard prone areas and/or in vulnerable and exposed settlements, in order to make settlements more resilient.

The framework provides, for the local urban development plan, site-specific solutions and tailored recommendations to private developers for existing and developing urban built areas to specifically address the issues aroused from the analysis of the case study, starting from the definition of planning objectives that could easily apply to similar contexts and are inspired by common acknowledged risk reduction guiding principles.To solve issues caused by the conflicting land use practices and urban sprawl as well as by conflicting intersections between the watercourse and the road network, thus defining new land uses and compatible transformations procedures according to each identified risk-based buffer zone, urban planners should be supported by the contemporary acquisition of both knowledge and public consensus, which together allow to embrace and justify a new and effective DRR zoning approach.

Clearly, the proposed framework cannot be considered comprehensive nor exhaustive of solutions for planners and interested local stakeholders, especially considering the complexity of urban issues concerning the water-related risk management and specificities of urban contexts. Forasmuch as the determination of normative rules and the consequent prohibition or land use modification may result in influencing the catchment hydrologic response in depth.

	Guiding Principles	Integrate sectoral and emergency plans into master plans	Start from guidelines and provisions of the FRMPs/PAIs and the Emergency Plans, to outline enlarging buffers by the stream axis	
		Detail the risk scenarios at the local scale	Advocate for stakeholders and experts involvement to provide risk assessment studies, hydraulic simulations and contextual evaluations of flood prone areas, urban land uses and morphologies at the local scale	
		Overcome traditional zoning in favour of risk-based zoning	Define new land use and compatible transformations procedures under a DRR approach and according to rules and restrictions coming from sectoral planning tools and results of risk scenario modelling	
Key criticalities	**Planning objectives**	**Recommendations**	**Expected results**	
Conflicting land use practices and urban sprawl	Nullify the sprawl in peri-urban and rural areas	-Apply the transfer of development rights mechanism according to risk-based zoning and land use/urban development susceptivity; -Issue specific "risk permission" for every planned urban transformation to be granted on the base of detailed hydraulic certification.	-Reduction of soil sealing and land cover modifications within the stream basin; -Diminution of human and goods exposition to hazardous events, with lower demand for hydraulic works and man-made alteration of the natural water course, due to rainfall shifting; -Public consensus and support due to developers financial compensation.	Developing areas
	Increase the resilience to flood risk	**In high-risk areas**: *Regulations* -Deny the issuance of new development rights; -Allow only ordinary and extraordinary maintenance activity under the condition of partial parcel de-sealing -Prohibit procedures for building amnesty. *Incentives* -Monetary and non-directly-monetary incentives to implement nature-based solutions with particular focus on sustainable urban drainage measures; -relocation zoning plan. **In lower risk areas:** *Regulations* -Deny the issuance of new development rights; -Ordinary and extraordinary maintenance activity allowed under the condition of partial parcel de-sealing -Procedures for building amnesty under condition of flood-proofing. *Incentives* -Monetary and non-directly-monetary incentives to implement nature-based solutions with particular focus on sustainable urban drainage measures.	-Induce the progressive transition towards conditions as much similar as the pre-development ones; -Provide a range of mechanisms according to risk levels encompassing alternatives from minimum single-owner actions to highly efficient multi-owners operations; -Create basic conditions for an extensive stream bed re-naturalization.	Existing areas

Conflicting intersections between the watercourse and the road network	Increase the resilience to flood risk	**In high-risk areas**: *Regulations* -Impede vehicular fruition conflicting with water flows **In lower risk areas:** *Incentives* -Provide an alternative to the existing road network, considering monetary and non-directly-monetary incentives, different form the traditional compensation for expropriation, for those private owners whose parcels would be potentially affected by the proposed mobility plan	-Diminution of human and goods exposition to hazardous events	Existing areas

Tab.1 Tailored recommendations to private developers for existing and developing urban built areas

Many limits could potentially hinder a proper land policy formulation, encompassing legal and technical barriers related to the implementation of the local urban development plan and zoning. For example, the difficulties in regulating existing built areas and in creating favourable conditions for encouraging retrofitting of private properties by eliciting landowners' willingness to pay for devoting a portion of their property to a green infrastructure measure (Pappalardo and La Rosa, 2020).

Moreover, best practices addressed to land safeguard and protection are challenged by the lack of political will, which is greatly influenced by the search for social acceptability, traditionally linked to the defence of the bundle of property rights.

Furthermore, in order to positively and properly impact, proposed regulations and incentives should be part of a scrupulous process through which the general compliance and consistency among other already existing regulations, ordinances and codes with regard to the whole aspect of municipalities assets must be verified. In this way, it is easier for developers to meet multiple requirements all together. In addition, this codes review process must rely on a sound coordination among the various departments involved in development permitting and could be easily nullified by the inertia of local interested stakeholders.

Most importantly, local planning needs legislative support from the institutional context and the normative and regulatory system.

3.2 The need of a risk-based approach in land use planning in Sicily: opportunities and barriers

Up till now, the local and regional planning laws in Sicily, have not paid a relevant attention to the risk issues. As a consequence, the planning practice did not take into account and include strategies oriented to DRR, both at the regional and local scale.

The only actions imposed by regionals act were related to restraints on new development in hazard prone areas based on sectorial plans such as PAIs or FRMPs, issued at the scale of the river basins.

A little step forward was done in June 2020, when the Regional Government enacted a new planning law, with the aim to overcome the 40 years old existing law in favour of a new act all-encompassing latest challenges of the contemporary planning practice.

Among the main principles, the control on a fully match between urban transformations and risk reduction, is recommended both for local and regional planning practices through a set of measures and actions that should be necessarily included in plans.

In particular, at the regional scale, the Metropolitan Plans should define a set of analyses concerning land transformations, taking into account natural risks such as volcanic, seismic, hydrogeological etc., and should provide measures oriented towards coping with risk prevention. In particular, the hazard prone areas must be identified, classified and mapped, using survey and data from Regional and local Authorities.

Likewise, city masterplans should identify hazard prone areas and buildings, specifying the different instruments and tools for risk mitigation. In this case, it is mandatory to prepare preliminary studies concerning geologic, hydrogeological and geomorphological issues, on the base of PAIs and FRMPs plans.
Concerning land use choices, the law provides planning tools and land use categories specifically related to risks management, such as urban regeneration practices oriented to risk reduction, and the total protection of vulnerable farmland.
In addition, the law includes for the plan the possibility to provide volume incentives, to transfer development right policies and to reduce taxes, in response to planning actions carried out by private landowners.
According to the new law's contents related to risk assessments, and in the light of the presented practical framework, the planning practice should definitively enhance the prevention culture as well as an administrative awareness concerning the risk issues under the DRR approach, in order to envisage new planning processes fully oriented to integrate land use plans with emergency ones.

4. Conclusions

Several researches assess the escalation in severity and frequency of climate driven hazards as consequences of climate change (IPCC, 2014, Banholzer et al., 2014), while others analyze and discuss the role of the anthropogenic factors, such as unplanned expansion of cities to accommodate rapid population growth, combined with inappropriate land-use planning and the lack in regulation of building standards, in determining the increase of risks levels for urban population (Gill & Malamud, 2017, Fidelis & Rodriguez, 2019). Despite full disciplinary awareness on the huge potential of cities for influencing improvements in the risk management, the issue of hazard prone areas is often not properly addressed in the planning practice. (King et al., 2016).
Due to the well know conditions of fragility of territories, there is an immediate need to adopt and put in practice a new integrated approach for urban planning and risk mitigation, with the aim to implement successful measures and actions based on site-specific risk reduction policies.
According to this emerging instance, this contribution has defined a set of proposals for increasing the effectiveness of actions taken by local administrations, at the stage of drafting and implementing local urban development plans.
The real challenge is thus to transform the risks in opportunity through the transition from emergency plans to new land use plans oriented to risk reduction (Sargolini, 2020). Many criticisms still burden local emergency plans, which may turn out to be too limited, to provide temporary buffer solutions, and cannot deal with the complexity of a comprehensive territorial vision nor have effects on the risk sources (Pilone et al., 2016).
Changing the old-fashioned established attitude that has generally characterized both those plans, means to abandon the actual partial vision borrowed from traditional disaster management, in favour of new comprehensive strategies and complex actions oriented to enhance risk reductions through the provision of specific land use categories and innovative planning tools for hazard prone areas.
Those provisions should be identified according to planning policies and related land use plans. Furthermore, the necessary integration can be achieved through a deep revision of management models and processes of both plans (Menoni, 2020).
The discussion opened up on the case study clearly shows how land use planning and practices may help in preventing future water-related risks. In particular, urban development plans can be profitably informed through targeted recommendation and inspired by cross-sectoral perspectives concerning land use and water protection, like reducing soil sealing, preserving river basins and enhancing water retention with nature-based solutions. The traditional approach related to land restriction has to be overcome by means of the development of integrated plans, in favour of the definition of more creative strategies. The latter, although unpopular, can effectively readdress mitigation principles towards new primacy objectives related to land protection, public interest and safety of citizens. It is also necessary to enhance the institutional and administrative culture of

risk reduction in terms of skills and awareness, in order to fully integrate risk reduction policies with other political choices related to the regional and city planning government, making the risk issue non-negotiable.
This paper, by approaching an emblematic case study for investigating the complex relation existing between urban and land use planning and water-related risk management, would also like to suggest some conclusions as take-home-lessons on which further researches need to be opened and conducted.

- Riverine flood risk in urbanizing watersheds evolves according to land use projections and impacts on the entire floodplain extent. There is a limited understanding of floodplain sensitivity to increases in overland runoff rates and volumes, since topographic factors, stream characteristics, and the presence of existing flood infrastructure influence the ability of a watershed to accommodate (Gori et al., 2019);
- It is important to re-define the weight of the technology, particularly the domain of hydraulic engineering, in shaping the future dynamics of the catchment. Few authors explore the influence of existing and planned hydraulic works, in mutual interaction with social responses and environmental processes, on the development of the entire territorial system over time and discuss options to realign unsustainable pathways with more desirable ones (van Staveren and van Tatenhove, 2016);
- No consideration of site-scale development policies, land use modifications, historical transformation of transport networks as well as of settlements models hinders the gain of a comprehensive knowledge on urban risk, which would allow to understand more on causes without limiting the concern to the visible effects of the damage during an emergency phase;
- Pursuing resilient urban development and design passes through a policy of careful decision making and land use planning, both informed by the knowledge gained on current and future risk scenarios, including the understanding of hazard, exposure and vulnerability of urban areas and how they combine when talking about water-related risks;
- While sectoral plans are important to prevent, limit and forbid, the alternatives in zoning, land use transformations and urban spaces configuration are intrinsic to the local development plan realm. Accordingly, despite being compulsory adopted by the masterplan, all safeguard/hydrologic/land use restrictions defined at the regional/basin scale should be understood such the necessary conditions, yet not the sufficient, to manage urban transformation at the local scale;
- New integrated plans should include general information about the main characteristics of the territory or the urban settlements interested by planning actions. They should be created through a considerable survey campaign, at the local scale, oriented to build a detailed analysis including risk scenario modelling and considering the combination of different types of hazards and vulnerability conditions (Barbarossa et al., 2020). They should set effective tools that, on the basis of an exhaustive and in-depth multi-risk analysis could be able to provide not only indications, but also a range of mechanisms for interventions and appropriate planning rules in the most vulnerable and exposed areas. In particular, plans should be able to categorize the main risks of the territory, highlighting where possible interactions between the hazards, and land use transformations, can provoke risk for population, structures and environmental and cultural heritage. City masterplans should also indicate the prevailing situations that require an immediate intervention to avoid serious damages and define proper tools intervention based on singular vulnerability;
- The masterplan must add creative and tailored solutions based on site-specific urban and environmental constraints as well as potentialities that might finally keep the local spatial planning stuck in its responsibilities towards the safe and resilient city target. Understanding potential effects of the act of planning, not only in altering property and tenure rights but foremost in affecting water-related risks, remains a crucial issue (Pappalardo et al., 2017).

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Image Sources

Fig.1: Authors (Data sources used for the analyses: "Risk Scenario" - Piano Comunale Protezione Civile, Città di Acireale; Aggiornamento del Piano Stralcio di Bacino per l'Assetto Idrogeologico (P.A.I.) - Carta del rischio idraulico per fenomeni di esondazione, Comuni di Aci Castello e Acireale; "Mobility" – orthoimages ATA, year 2007-2008 – Google Earth images; "Urban Growth" – IGM Italian Geographic Military Institute cartography, year 1924 - orthoimages STR, year 1964 – CTR sicilian Regional Technical Cartography, years 1985/1999/2007 - orthoimages ATA, year 2007-2008 - Google Earth images; "Land Use" – orthoimages ATA, year 2007-2008 – Google Earth images)

Fig.2: Authors (base maps: Google Earth)

Fig.3: Authors (base maps: Google Earth)

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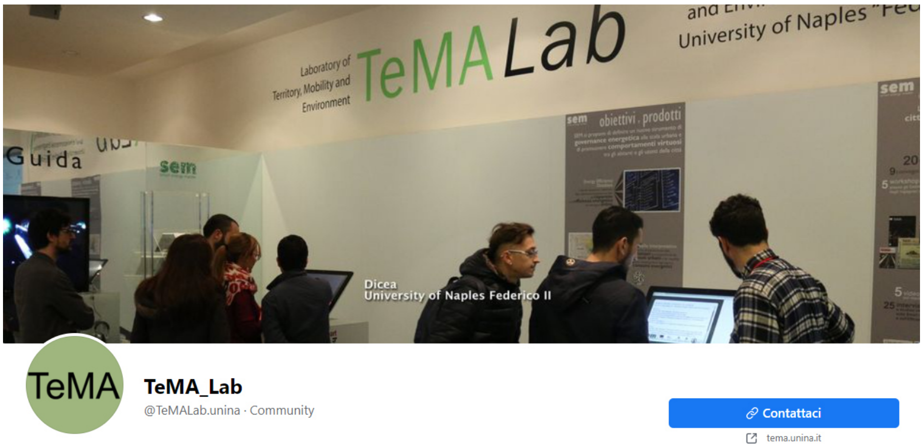

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Evaluation vs landscape planning in the Italian framework

Is risk prevention a utopia?

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Abstract

Territorial management can be implemented through an intervention perspective concerning a plurality of characteristics inherent to natural and artificial resources, in order to guarantee protection of environmental and territorial identity. The thesis, to be addressed in this paper, concerns the question of whether landscape planning is able to prevent and protect against the risks deriving from poor management of the territory. In particular, in Italy the Landscape Plan, in the role it assumes under the so called Urbani Code, recognizes the value of the territories in an attempt to direct the safeguarding and restoration of landscape values. In this paper the role of Strategic Environmental Assessments in the prevention of risks in the hypothesis of reasonable alternatives has been analysed.

Keywords

Territory; Landscape planning; Risk; Indicators.

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1. Introduction

For the verification of the effects of the plan, the choice of the indicators in their dual value - qualitative and quantitative - is of fundamental importance. The indicators, as information capable of describing the spatial-temporal changes of the territory, involve environmental and perceptual landscape issues related to natural ecosystems, biodiversity, landscape, transport, cultural heritage, and energy.
The topic is the subject of numerous investigations: they were conducted by researchers who study manifold aspects of the territory and landscape and therefore identify the aspects related to their disciplines. What unites most of the research, albeit coming from different scientific interests, is the relationship between the phenomena of instability on the territory. These events are mostly connected to the widespread landslide and erosion phenomenon at a territorial level in many European countries and also worldwide. Furthermore, recent scientific research is increasingly oriented towards investigating the effects of climate change on these phenomena.
Landslide phenomena therefore affect a large part of the world and have certainly been aggravated over time by the increase in the building of settlements in particularly fragile areas. Landslides involve flowing, sliding, overturning, falling or spreading, and many landslides show a combination of different types of movements, either simultaneously or during the life of the landslide (Gariano & Guzzetti., 2016).
Sloping areas are, by their nature, unstable and the monitoring of such phenomena is a crucial issue. Added to this fragile nature are phenomena that negatively affect and contribute to the accentuation of the phenomenon: volcanic activity, seismic activity, precipitation (rain and snow) and, of course, the abrupt climatic changes that characterize recent years.
Geological and meteorological scholars advance increasingly detailed hypotheses on future scenarios (Seneviratne et al., 2012; McInnes et al., 2007; Crozier, 2010; Dijkstra & Dixon, 2010; Coe, 2012) and, above all, define the close relationship between temperature variations and the increase in sudden and violent precipitation.
Furthermore, many studies have been carried out on flood risk, especially in Europe (European Union, 2018). Italy is the European country which faces most hydrogeological risks due to climate change and this is also demonstrated by the latest studies by the EU. This was stated by the ANBI (National Reclamation and Irrigation Association), according to which Italy "is the European country most exposed to soil erosion, caused by the extremes of atmospheric events".
In Italy, according to ISPRA data, there are about 620 thousand landslides affecting 7.9% of the peninsula. This percentage rises to 16.6% (100% of the territories of Valle d'Aosta, Liguria, Emilia Romagna, Tuscany, Umbria, Marche, Molise, Basilicata and Calabria) including hydraulic hazard areas. More than five million people and about 79 thousand companies operate in areas with high landslide risk, while about 9 million people and 576 thousand businesses are in flood risk areas (ISPRA, 2018).
Spending capacity compared to the funds disbursed by the European Union also faces much criticism: "Yes, because from 2007 to today, according to the data of the Ministry for Cohesion, the Italian regions have presented about 700 interventions for the safety of the territory within the 2007-2013 and 2014-2020 ERDF programs. But they have just concluded 333, less than half, for an amount of payments received that is around 320 million euros. If you look at the resources allocated in the old ERDF and those programmed until 2020, Italy should have spent 1.6 billion in European funds by that date. Basically, we are at just under 20%" (Prestigiacomo & Lecca, 2018).
In this field too, numerous projects are being developed, such as a decision support system for eco-engineering solutions to slope stability problems. It is the first management tool of its kind, which aims to combine ecological and bioengineering techniques on the ground with easy-to-use software (Eco-engineering and conservation of slopes for long-term protection from erosion, landslides and storms). And numerous projects are being implemented, also under the Horizon 2020 funds, such as the "COproductioN with NaturE for City

Transitioning, INnovation and Governance" (European Commission, 2017-2022) which aims to find collaborative solutions for more sustainable, resilient, greener and healthier cities.
Some scientific studies show the positive results deriving from the interaction between biodiversity, ecosystem services and green urban infrastructures. In this sense, NBS (Nature-Based Solutions) have emerged as the main political engine for most cities in transition, because they can be used to create multifunctional arenas and fulfil multiple social, economic and environmental objectives simultaneously.
Another important line of research then turned to the role played by social behaviours. In recent decades, the impact of natural hazards has increased due to a rise in population density in hazardous areas, often associated with poor planning, and the increased frequency and intensity of extreme events as a result of climate change. The conditions of populations living near volcanic areas are very particular (in Italy the cases concern Mt. Vesuvius in Campania and Mt. Etna in Sicily). Disasters vary drastically depending on the local context. Indeed, the likelihood of a natural disaster having more devastating effects in one place than in another depends on the local vulnerable components of the affected population (cultural, social and economic). Therefore, there is an important correlation between potential risk and social resistance and resilience of a specific place, so the response to the disaster varies depending on the social fabric.
This paper analyses the panorama of the landscape planning process, focusing attention on the procedures of the Strategic Environmental Assessment (SEA), and focusing on the fact that the Regions have implemented the application of the SEA for Landscape Plans in a diversified manner.
Regarding article organization, the introduction is followed by paragraphs dedicated to the definition of the research methodology (paragraphs 2, 3 and 4), the description of the elements that emerged in the case-study of the Molise Region (paragraph 5) and the conclusions including some food for thought and considerations regarding the continuation of the research.

1.2 Raising planning awareness

Territorial transformation could be analysed through the set of cognitive identification, evaluation, planning, localization and intervention implementation, as well as supervision and control. These actions are aimed at pursuing the protection and enhancement of the territory and the regulation of uses and transformations in relation to development objectives.
The tools that regulate the aforementioned land management processes are the plans.
The plan is a tool for governing the whole territorial process that aims to implement widespread and shared policies with which it is possible to increase the usability, competitiveness and attractiveness of the territory.
Particular attention should be paid to the concept of landscape protection, which is the product of the stratification of natural phenomena and anthropogenic transformations over time. By nature, therefore, the landscape is not static, that is, it cannot be reduced to one, or a set of still images, of "panoramic views", but must necessarily be interpreted through its evolution over time. It can only be interpreted by walking through its spaces, and trying to read and reconstruct the traces of the different systems of relations that have alternated and overlapped over time.
The Landscape Plan, as understood in the Italian Code of Cultural Heritage and Landscape (Repubblica Italiana, 2004), provides for the adaptation of urban planning tools to the provisions of landscape planning and must have descriptive, prescriptive and propositional content. The objective of the Landscape Plan is to allow a survey of the entire territory, through the analysis of the historical, natural, aesthetic characteristics, of their interrelationships and the consequent definition of the landscape values to be protected, recovered and redeveloped by identifying landscape areas with the related landscape quality objectives. It is of fundamental importance that the provisions of these plans are able to be far-sighted, able to focus attention on the individuality of each territory and ensure excellent management of available resources, to make the territories of 'smart lands' increase their competitiveness.

3. The Strategic Environmental Assessment: the choice of indicators

The Strategic Environmental Assessment tool allows the evaluation of environmental effects resulting from the implementation of the plan forecasts and to hypothesize reasonable alternatives. The SEA process is structured following the indications of Directive 2001/42/EC relating to the environmental assessment of Plans and Programs and has been implemented in the Italian legal system with Legislative Decree 152/2006 and its subsequent amendments.

The SEA is a process aimed at ensuring that the significant effects on the environment deriving from its implementation are taken into account in the creation, implementation and approval of a Plan or Program. This does not represent an authorization procedure in itself or an evaluation of the contents but consists of a process in which the evaluation accompanies the whole planning process and where the competent authorities for the SEA and those groups with environmental expertise ensure their collaboration to guarantee the tool's sustainability. The SEA is therefore not only an evaluation tool but a process that contributes to the definition of the choices to be made within the plan or program. The objective is to identify the effects that will derive from the implementation of the plan or program choices in advance, thus allowing the selection of possible solutions among the alternatives most in line with the principles of sustainable development. Fundamentally important for understanding the effects deriving from the plan is the choice of indicators which have a double value: qualitative and quantitative. This is information capable of promptly describing both spatial and temporal changes in a territory and can be of different nature.

The definition and organization of indicators is a very important aspect of strategic environmental assessment as these are elements of connection and coherence between the different phases of the assessment. The set of indicators must make it possible to highlight the environmental and territorial characteristics of the area potentially affected by the effects of the plan, to assess the significant effects due to the actions envisaged and to monitor the implementation of the plan and the level of achievement of its targets. It is useful to choose a sufficient number of indicators on the basis of their effective ability to represent a given phenomenon (Bruni, 2016; Carvalho de Assis Dias et al., 2020; Walza & Steinb, 2018; Syrbe et al., 2018; Nowaka & Grunewaldb, 2018).

Only through an overall reading of various aspects, and therefore considering a plurality of indicators and the relationships between them, is it possible to understand how different a weight each one can have and how much it can contribute to making an effective evaluation of the plan.

The main topic of this study is the use of the Strategic Environmental Assessment for the plans, focusing on its application to the Landscape Plans. mThe evaluation process involves numerous competent subjects in environmental matters (Łowicki, 2017; Uuemaa et al., 2009, European Commission & Italian Environment Ministry, 2003; Cassatella & Peano, 2011), and, in harmony with national and regional legislation, is divided into a series of phases which are: the carrying out of a verification of eligibility limited to the plans and programs referred to in Article 6, paragraphs 3 and 3-bis of Legislative Decree 152/2006; the preparation of the environmental report; carrying out consultations; the evaluation of the environmental report and the results of the consultations; the decision; information on decision making and monitoring. The choice of indicators to carry out the SEA of the Landscape Plans is based on issues relating to the territorial context through the analysis of the current aspects, analysing the environmental issues thus taking into consideration different components, including environmental (air quality, climate change, water, soil and waste) and perceptive factors (natural ecosystems, biodiversity, landscape, transport, cultural heritage and energy).

4. Methodology

The SEA procedure is aimed at providing cognitive and evaluative elements for the formulation of the hypotheses of the plan allowing the documentation of the underlying reasons for the strategic choices to be made. Therefore, this paper focused on the methodologies adopted for Landscape Plans in Italy.

In the first instance, the study of the evaluation procedures already concluded has been deepened, in comparison with references to the above-mentioned landscape indicator literature, at national and international level. This analysis has been carried out, as will be specified in the case-study paragraph, in order to draft the Landscape Plan of the Molise Region.

The regions have implemented the indications concerning the application of the SEA for the Landscape Plans and each one identifies the main issues to be evaluated and is in a different phase of the SEA procedure.

The majority of the regions have reached the stage of drafting the Environmental Report which identifies, describes and evaluates the significant impacts on the selected components, the reasonable alternatives in light of the territorial scope of the plan.

It also contributes to the definition of the objectives and strategies of the plan and indicates the environmental compatibility criteria, the reference environmental indicators and the monitoring methods.

The Regions should control the planning process through the SEA. To do this, it is useful to be able to have environmental sustainability objectives, consistent with the supra-local development policies for the territory, as well as indicators to measure territorial transformation processes and to evaluate the contribution of the plan to the achievement of the general sustainability objectives.

The Strategic Environmental Assessment (SEA) - as an administrative procedure aimed at ascertaining the environmental compatibility of plans and programs - anticipates the insertion of environmental considerations in public decision-making processes (in application of the prevention principle). This allows the influence of administrative activity of a general nature and reaffirming the transverse nature of environmental issues. The Italian national environmental law (Repubblica Italiana, 2019) had established that all plans and programs with significant impact both on the environment and on the landscape (i.e. cultural heritage in which landscape assets are included) would be assessed. It specified, in fact, that the impact on specific factors (human population and human health; biodiversity; territory, soil, water, air and climate; cultural heritage and landscape) must be assessed not only individually but also on how they interact with one another (art. 5 and art. 6). It also introduces the concept of visual perception and the need for improvement measures (for example for the production sites of excavated earth and rocks).

Deepening the analysis on landscape issues, many studies have been made on "Landscape Character Assessment": "The character of the landscape can be defined as the presence, variety and arrangement of landscape features, which give a landscape a specific identity and distinguish it from the surrounding landscapes. The landscape character contributes to the aesthetic and perceptive value of an area" (Jellema et al., 2009) deepening in the various application cases typical aspects of the disciplines that have dealt with the topic from time to time (Butler & Berglund, 2014; Bartletta et al., 2017; Tudor, 2014; Vogiatzakis, 2011; Griffiths, 2018).

It is certainly more complex when thinking of a SEA specifically applied to urban planning tools. In Italy, the Landscape Plan is drawn up and approved by the Regions, in agreement with the Ministry of Cultural Heritage. The implementation of the SEA is entrusted to the Regions themselves. However, the State is responsible for the approval of the other plans and programs; the implementation of the SEA is the responsibility of the Ministry of Environment, assisted by the Technical Commission for the verification of the environmental impact.

At present, there are not many the concluded SEAs procedure for the Landscape Plans in Italy and they have been addressed with different approaches. By carrying out a critical review it would be useful to weigh, expand and integrate the various components to be analysed, considering different fields and disciplines to have a multi-sectoral and broad spectrum vision.

To do this, it is necessary to differentiate the type of indicators according to the specific plan to be evaluated in order to understand how the various elements interact and contribute to generating planning capable of evaluating the consequent evolutionary dynamics. Besides a more careful choice of indicators according to the type of plan, it would be desirable to define specific analysis methodologies based on the type of topic and the study context; not limiting itself to the application of the same analysis regardless of the evaluation theme.

A further aspect on which the urban planning discipline could improve this type of evaluation is to face a more in-depth discussion about the actions to be implemented. These must be based on the desire to control future events by identifying the potential impacts on the environment by the plan guidelines and choosing the best courses of action from the various alternatives.
At the European level, therefore, all countries should comply with the dictates of the aforementioned Directive 2001/42/EC, which strongly emphasizes the importance of assessing the likely effects of plans and programs on the environment. But very often in the phases through which this evaluation is carried out it is not possible to include - or at least not sufficiently - the concept of prevention. All this, despite the fact that the Directive states that the Community's environmental policy - as well as contributing to pursuing the objectives of safeguarding, protecting and improving the quality of the environment - must be based on the precautionary principle, favouring actions that promote sustainable development.
The question that seems appropriate in this discussion is, therefore, whether the mechanisms of the Plan's Strategic Environmental Assessment really have a preventive effect with respect to risk factors. Or rather how much such mechanisms can contribute to risk prevention.
In this paper, the major attention is aimed at introducing specific metrics for the assessment of "people perception". They are introduced both to deepen the prevention aspects and the aspects relating to landscape change: the greatest difficulty lies in calculating the effects of the landscape "detractors". Therefore - since Italy is subject to an infinite combination of risks - an attempt has been made to make a distinction between the detractors of identity character and the detractors of security.
In the comparison made with the methodologies used in other countries, great attention was paid to indicators: they mainly measure the effects on the elements of the environment or are oriented towards the definition and development of indicators that were capable of measuring landscape quality (Cialdea, 2007a; Cervelli et al. 2018). For a theoretical study (useful in order to answer the question that this study poses, or whether the strategic environmental assessment really manages to have a preventive effect), the research was carried out starting from the analysis of the indicators used in the VAS already implemented in order to make a comparison for a definition useful for application to the case study that is set out in paragraph 5.
The methodology's flow chart followed in this report is shown in Figure 1. A decision was made to investigate the phase of risks linked to physical instability and difficulties perceived by the population and to evaluate these factors through the creation of two grids, the Modification Map and the Resilience Map. The comparison of these two maps, within the SEA of the Landscape Plan, will be useful for the definition of those indicators that in Figure 1 are defined as C, S, V and F from the above mentioned literature.
The verifications of these indicators are being drawn up.

5. The Molise case-study

5.1 A long seismic tradition

In some areas, such as the case of the Molise Region, the presence of telluric phenomena is so constant that it becomes itself the element of identity. The earthquake in Molise is a common thread that has bound the people of Molise over the centuries. A succession of these phenomena characterized the story of this area from 280 B.C. until the last large seismic event occurred in 2002 with the tragic events in San Giuliano di Puglia (Repubblica Italiana MiBACT, 2003).
The oldest known earthquake is conventionally dated to circa 280 B.C. Evidence of this event has been found in so-called "archeo-seismic" studies, carried out on the Samnites Hercules Sanctuary in Campochiaro. A brief inscription on a tombstone marks a really destructive earthquake which took place at the end of the first century A.D., while San Girolamo describes an earthquake conventionally dated 346 A.D.

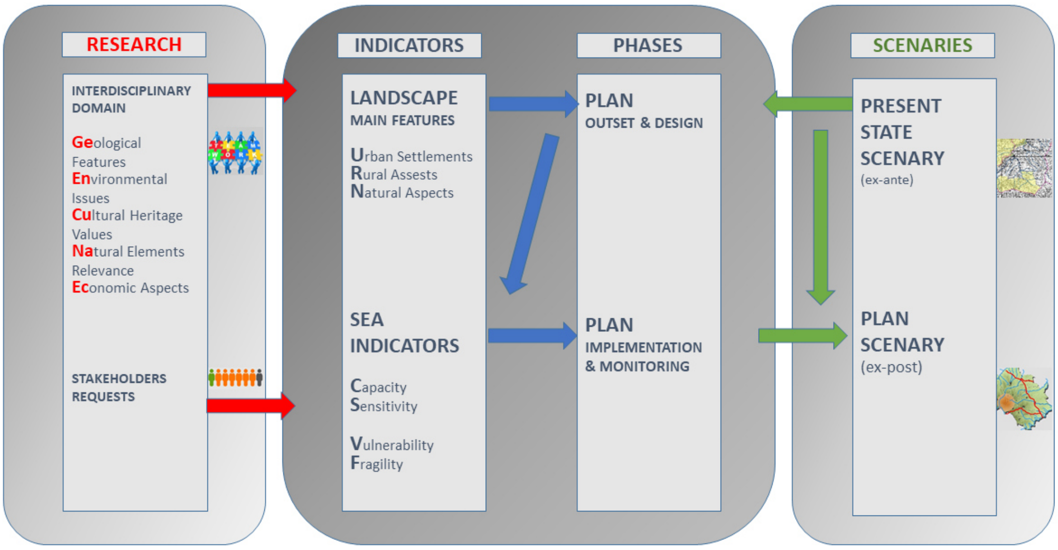

Fig.1 The Methodology's Flow-chart (Source: Lacosta Laboratory, 2017)

After this event the government had to rebuild all over the Molise area from Venafrum, to Aesernia, Bovianum and Saepinum. Until then Sannio was a single Roman Province with the Campania Region and it seems that it was just the state of emergency after the earthquake that led local people to create two distinct administrative units in order to facilitate reconstruction purposes. The governor Fabius Maximus carried out a lot of reconstruction, especially in Saepinum. Thanks to *Cronica Sancti Benedicti Casinensis*, there are records of another event in June 847 in the Benevento Principality (which then included all of the modern Molise Region) that caused a number of deaths and great devastation in the area between Isernia and San Vincenzo al Volturno. The 1294 earthquake is known only through a series of tax exemptions issued by Carlo II D'Angiò in favour of people affected by the earthquake. The most affected location was Bojano where there was "a great massacre of men and women".

In the middle ages two important seismic events struck the Molise Region: the earthquake on September 9, 1349 and that of December 5, 1456. Both of these earthquakes were the largest and most catastrophic that had occurred in Italy in the last 1000 years. The first one provoked several thousand victims which added to those caused by the plague epidemic of the previous year. Also the second, known through a manuscript of the humanist and diplomat Giannozzo Manetti, was a series of events activating numerous faults along the Apennine Chain. It provoked thousands of deaths and razed many churches and medieval castles to the ground in the central Molise area.

In the seventeenth century, there were two seismic events that interested two different areas of the region. The earthquake on July 30 1627, with its epicentre in the North part of Apulia, caused partial damage in Termoli and in Campomarino. Moreover, there was a devastating earthquake June 5 1688 generating effects in the Sannio Beneventano area up to northern Irpinia causing over 10.000 victims. The eighteenth century was characterized by a single seismic event that occurred November 3, 1706, known as the Majella earthquake. This event destroyed the city of Sulmona and led to 2000 deaths.

The nineteenth century was marked by the earthquake of 26 July 1805 (known as the Sant'Anna earthquake): the earthquake was strong enough to be felt in Naples and caused serious damage n the cities of Isernia and Campobasso.

In the twentieth century there were a number of seismic events. The earthquake on October 4, 1913 with its epicentre in the central part of the region, South of Campobasso, was not as devastating as previous events.

The January 13 1915 earthquake, the Fucino earthquake, was one of the biggest natural disasters in Italian history and led to the death of 33.000 people. In Molise it caused serious damage in the Volturno area up to Venafro and Isernia.

Events in 1930 and 1962 occurred in Irpinia. The first one, the more disastrous of the two, claimed 1400 victims with some damage in Molise. The May 1984 earthquake, with its epicentre in the Meta mountains, bordering the Molise Region, seriously damaged the area of the Isernia Province (Cialdea, 2019).

The last tragic event occurred October 31, 2002 devastating San Giuliano di Puglia and causing the death of many young people. It was characterized by two main shocks, of more or less the same strength, and it was followed by a seismic swarm lasting several months. This earthquake was significant, however, also at the national level, since following this event the seismic regulations at national level changed. In fact, the new seismic classification of the regional territory was carried out with Resolution no. 194 of 20 September 2006 (Regione Molise, 2006), containing the updating of the list of seismic zones according to the general criteria contained in the Decree of the President of the Ministers Council no. 3519 of 28 April 2006 (Repubblica Italiana, 2006). This Decree provided the Regions with indications for defining the seismic hazard of their territory, if they did not intend to implement the classification of Annex I of the previous OPCM no. 3274/2003 (Repubblica Italiana, 2003), (faculty allowed to the Regions by the Legislative Decree 112/1998 which attributed to the Regions the functions of identifying seismic zones and of training and updating the relative lists, invoking the State task of defining the general criteria for carrying out this activity).

The Molise Region, therefore, after having issued its own regional laws, no. 13, 17 and 21 of 2004 (Regione Molise, 2004a, 2004b, 2004c) approved a new re-classification, increasing the number of municipalities in the area at greatest risk, i.e. zone 1. In fact, before 2002 earthquake, there were 104 seismic municipalities (of which only 3 with grade 12, i.e. Castellino del Biferno in the province of Campobasso and Castel del Giudice and S. Pietro Avellana in the province of Isernia). With the subsequent law of 2004 all 136 municipalities of the Region are reported, 26 in zone 1, 95 in zone 2 and 15 in zone 3.

The subsequent resolution of 2006, finally, pays attention to risk and therefore of the 136 seismic municipalities, 43 fall into zone 1, while those in zone 2 go from 95 to 84 and those in zone 3 from 15 to 9 (Cialdea, 2007b, 2017, 2020).

5.2 Territorial Protection

The territory of the Molise Region is characterized by great fragility. This fragility largely depends on its geo-lithological structure. Hydrogeological instability has always represented a significant social problem for the Molise community due to the disastrous landslides and / or alluvial phenomena that involved both inhabited areas and communication routes.

The above-mentioned seismic event, for example, marked a milestone, also because it was then followed by another major meteoric event: the two calamities, the earthquake and the flood event, caused the triggering of new landslides, and the reactivation of many quiescent phenomena (Aucelli et al., 2003, 2004; Rosskopf & Aucelli, 2014).

Needless to say, these phenomena have become more and more frequent in recent times, due to the repeated phenomena that occur throughout Italy but which record critical situations in the increasingly fragile territory in question, more and more frequently leading to the regional government asking for the declaration of a state of emergency. In the region, in fact, 100% of the municipalities are affected by landslide hazard areas P3 and P4 and / or P2 for hydraulics risk and is among the five Italian regions (with Valle D'Aosta, Liguria, Abruzzo and Basilicata Regions) with higher risk values for the resident population in these areas (ISPRA, 2018, IDROGEO Web Portal). Already with the law 9/7/1908 n. 445, which represents the first legislative reference of national value for the official recognition of those situations of instability concerning inhabited centres, implementing measures were also issued for two Molise villages (Castellino sul Biferno and Rocchetta al

Volturno). Subsequently, up to the 1970s, 42 settlements in the province of Campobasso and 16 settlements in the province of Isernia were classified to be consolidated and / or transferred, for a total of 58 inhabited areas in poor conditions or in precarious conditions of stability (compared to 136 municipalities in the region, it is more than 40% of the total). Subsequent investigations by the region highlighted alternative situations for inhabited centres affected by landslides for another 11 municipalities in the province of Campobasso and 18 municipalities in that of Isernia.
Undoubtedly, conditions have progressively worsened in relation to urban planning choices because many of these areas have been inappropriately chosen as areas of urban expansion with inevitable negative consequences on the stability of the areas themselves and with serious damage to what has already been built. Too often, in fact, anthropic activities have been aimed only at maximum profit and have neglected the "basic cognitive analyses and reconstructions of evolutionary models" capable of allowing, where possible, the formulation of hypotheses and forecasts on potential disastrous phenomena. These scenarios would be able to activate preventive measures at least able to reduce, if not reverse, the negative effects.

5.3 Risks, human activities and the landscape

The choice of anthropic sites, therefore, causes major changes to the landscape and an important role is naturally played by urban planning tools. In the region under examination there is a large deficit with regards to this issue. Molise is currently devoid of Province Territorial Plans, even if a preliminary study for the Isernia Province was planned but never carried out and a study about functional matrices was drawn up in 2005 for the Campobasso Province – this also never concluded.
The Plans of the two Molise Provinces, as already highlighted, are not yet operational, while the Master Plans have already been adopted by the municipal administrations and, in some cases, are already approved and operational. Consequently, in addition to the general delay that characterizes the urban situation of the area under study, the quality of the tools in force, or in progress, is also limited by the absence of guidelines at the supra-municipal level.
Of all the Molise Municipalities (136), the overwhelming majority adopted the simplified Building Plan as an urban planning tool with the related Municipal Building Norms. On the contrary, only a little more than twenty municipalities have adopted the Master Plan, while for a municipality in the province of Isernia the Building Regulations apply exclusively and for the aforementioned Municipality of San Giuliano di Puglia the Reconstruction Plan has been in place since 2004. Therefore, the only vast area tool already existing in the region is the Landscape Plan, drawn up under the Galasso law (Repubblica Italiana, 1985).
The Landscape Plans currently in force in Molise were adopted in the early 90s and approved during the following decade: they do not cover the whole region, but leave some large areas uncovered, like that of the municipality of Isernia with some neighbouring municipalities and above all a large area of central Molise, including Campobasso, the regional capital.
The Regional Law 1 December 1989, n. 24 (Norms for Landscape-Environmental Territorial Plans) established that all urban plans, sector plans and programs must be compatible with the provisions of the landscape plan. Furthermore, it provides for the identification, assessment and indication of the protection methods and enhancement of the protection of elements of public interest; it also requires that the contents of the plans be binding for private individuals and take precedence over the activities of Local Authorities. So in Molise, a region where land-use planning is lacking, the operation of landscape plans plays a significant role.
The mechanism underlying these plans was to make up for the lack of a regional cognitive framework of environmental matters, which unfortunately is also accompanied by an unclear will of the regional policy. In essence, the Landscape Plans did not want to define the current use of the territory, instead highlighting a methodology to characterize the possible uses compatible with the current conditions of the sites. The plans,

in fact, were considered opportunities to define the guidelines for a project in the area, a procedure that would not have been necessary if a Regional Urban Planning Law had already been in place.
Therefore, there is a classification of defined homogeneous areas, for which from time to time we try to define compatible uses, with the consequent ambiguity deriving from having juxtaposed areas in which values of exceptional value are recognized, and which are given strict restrictions, to areas in which, since particular elements are not highlighted, it is possible to intervene without problems. As regards the basic philosophy of the plans, it can be said that it is aimed at defining the transformability of the territory, based on the value of the elements already mentioned by the law, therefore concerning the natural and anthropic, qualitative and quantitative features, also analysed in their historical stratification.
At present, the Molise Region has entrusted the preparation of the New Regional Landscape Plan pursuant to the already mentioned “Urbani Code” (Repubblica Italiana, 2004) to the University of Molise (and in particular to the laboratory directed by the writer) (Regione Molise, 2019).
The documents of this new plan were drawn up with the primary objective of identifying the situations of greater deterioration and alarm for the landscape system of the region. In particular, in the light of the above considerations, ample space has been dedicated to the topic of vulnerability, so widespread in the regional territory. Therefore, the map of Landscape Evidence of Hard Sites (Fig. 2) has been drawn up: it describes the areas with the greatest concentration of problems or the whole regional territory. In this map, the results of the geological grid carried out on the presences identified in the analysis map were identified throughout the region. Five types of indicators have been taken into consideration (hydraulic risk, geological risk, the settlements to be consolidated and / or transferred, the surfaces subject to seismic constraints and those subject to hydrogeological constraints) and for each of them a grid based on the specially defined weights. They are summarized in Table1.

6. Conclusion and remarks

The investigation being carried out wants to answer the question: what can the role of the planning tool really be in the protection of the territory and the landscape?
The topic was addressed in particular with regards to the vast area planning tool, and in particular by analysing the panorama of Landscape Plans in Italy.
In general, there is no lack of technical knowledge of hazard phenomena, but in planning activities, both at general and sectoral levels. If on the one hand a sufficiently exhaustive image of the preconditions of risk exists, on the other, however, it’s hard to carry out real risk prevention.
For this reason, the research focused on the choice of indicators.
Therefore, the indicators analysed relate to the verification of risks, as identified by the current sector plans as regards the classification with respect to risk (geological and hydrogeological). Furthermore, the surfaces of the region subjected to constraints (hydrogeological and seismic) were evaluated and finally the surface of the inhabited centres subject to a particular restriction was also evaluated, which concerns the identification of inhabited centres (or part of them) as inhabited by consolidate and / or transfer, included in the L.445 / 1908 and subsequent acts.
Specific reference is made to hydrogeological risk, since studies in this field are strongly linked to the geomorphological study of the territory and hydrographic networks, especially for the control of floods and river floods. Territories involved in these phenomena undergo very rapid changes and the recognition of these phenomena allows the understanding of the evolutionary tendencies of the transformations.
Of course, seismic activity amplifies the weakness of the soil linked to hydrogeological instability. However, it is a factor strictly linked to the structures of buildings and involves the sphere of their design, regulated by specific regulations on the matter. The Region under study, as highlighted in this paper, was sadly known for the 2002 earthquake, which led to the changing of regional norms and changing of national classification.

Certainly, some elements have been identified among the indicators, especially with reference to the safety of public structures and infrastructures.

	INDICATORS	WEIGHT
HYDROGEOLOGICAL RISK	Risk Classes	
	R1	1
	R2	2
	R3	3
	R4	4
GEOLOGICAL RISK		
	R1	1
	R2	2
	R3	3
	R4	4
HYDROGEOLOGICAL CONSTRAINT	Localization	
	Existing	2
	Not-Existing	0
SEISMIC CONSTRAINT	Acceleration	
	0,125	1
	0,150-0,75	2
	0,200-0,225	3
	0,250-0,275	4
URBAN CENTERS TO BE CONSOLIDATED AND / OR TRANSFERRED	Included in the L.445/1908 and subsequent acts	
	To be consolidated	2
	To be transferred	2
	To be consolidated and transferred	4

Tab.1 Main indicators utilised in the creation of the Hard Sites Map (Source: Lacosta Laboratory, 2019)

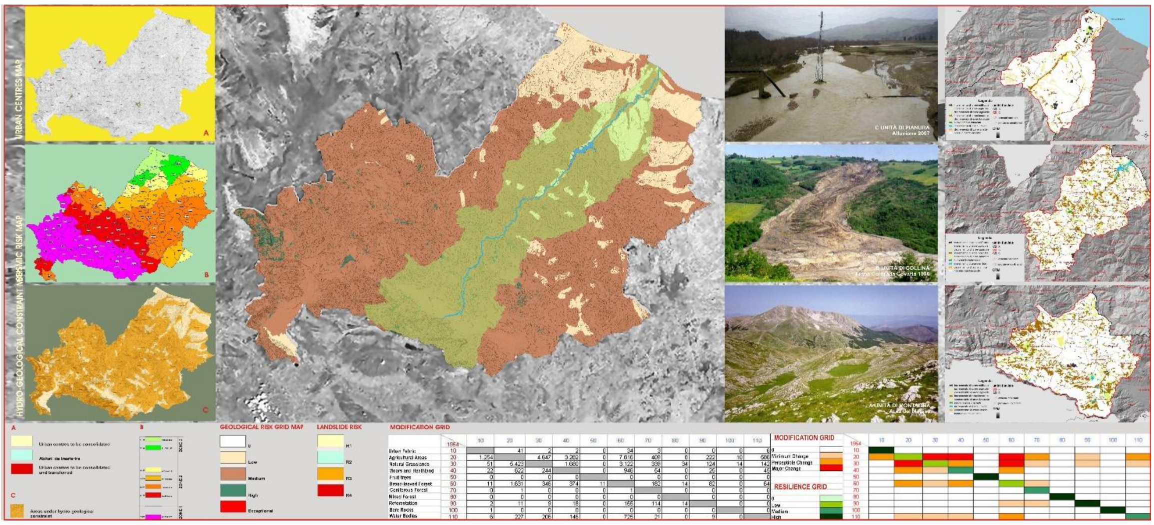

Fig. 2 The Landscape Map: Hard Sites related to main changes (Source: Lacosta Laboratory, 2019)

The biggest problem, however, is related to hydrogeological risk: although numerous studies and sector plans highlight the areas with the greatest issues (depending on the risk and on the hazard), they are trivially reported within the municipal urban planning tools, while it is also necessary to deepen the relationship with what surrounds these areas, with more definitions and indications.

In conclusion, the thesis aims at supporting the basic idea of the need for adaptability to territorial situations. In Italy the physical conditions vary greatly from one region to another. As shown, the regulatory systems in some cases are insufficient. The field of at-risk areas is where it is possible to investigate more deeply; this includes social phenomena, and connections between economy and ecology. The multiple factors that define a possible future of the territory, give value to the concept of prevention.

The definition of risk prevention, protection and restoration policies is fundamentally integrated with other protection strategies for specific sectors (air, water, ground resources and the landscape itself), and, therefore, the idea that soil degradation can also pose a risk to the population.

This has contributed to the launch of research into specific fields for the definition of tools for assessing risks to the soil, the impacts on the ecosystem and the economy, assessing the soil quality and the value in relation to the soil consumption to identify strategies of limitation in use, compensation and mitigation but above all to the production of a numerous series of projects and experiments. This work, however, looks to investigate the 'big picture', trying to contribute to and build upon the existing studies on this topic.

The in-depth analysis of the indicators normally used for the purpose of verifying the sustainability of a plan were applied in the drafting of the SEA of the landscape plan, which in the region in question is the only existing vast area tool. There remains little doubt that further efforts are needed in order to tackle the problem of non-emergency related prevention and this task can only be accomplished by an ever greater awareness of the development of urban planning tools.

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Spatial knowledge for risks prevention and mitigation

The civil protection planning of the Abruzzo Region

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Abstract

The scientific research described in this paper concerns the theme of Civil Protection Planning at Regional level and Disaster Risk Management. In particular, it concerns the definition and experimentation of a particular model of basic Knowledge System.

This model, which has been tested within the definition and predisposition of the 'Knowledge elements of the Abruzzo Region territory and civil protection organization of the Abruzzo Region (It)', is the result of a continuous and dynamic technical-scientific action, whose structure must necessarily be flexible in order to collect and analyse data and information concerning themes, the risks, which are constantly changing. In the research, an original analytical methodology of the Knowledge System has become the basis for the experimentation of a Regional Management Risk Plan (case study Abruzzo Region), a part of the Regional Civil Protection Plan, which allows to identify the Hotspots, i.e. areas characterized by very high and probably simultaneous risks, in which it is strictly necessary to identify prevention and mitigation interventions, the 'Territorial Prevention and Recovery Projects' that concern the structural activities of civil protection. The next steps will concern the definition of the methodology for the construction of a Digital Knowledge Platform for the establishment of a Spatial Information Modeling.

Keywords

Civil protection pan; Disaster risk management; Knowledge system.

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1. Introduction

A research of the University of L'Aquila (ICEAA Department) carried out in collaboration with the Abruzzo Region (It) is addressing the issue of the role of knowledge in the context of Civil Protection Planning, oriented in particular to the study of a Regional Management Risk Plan (RMRP), a very specific plan that can be considered an element of Civil Protection Planning. The RMRP, which is based on an important Knowledge System focused on Multi-Risk (Gallina et al., 2016; Kappes et al., 2012), relates to the general theme of Disaster Risk Management (DRM), i.e., a control task with many actors, factors, and scales, which is becoming increasingly central in the context of Civil Protection Planning due to both climate change and catastrophic events that have repeatedly affected areas such as central Italy, particularly the Abruzzo Region (Di Ludovico & Di Lodovico, 2020; Poljanšek et al., 2017; Norton et al., 2015; Rasmussen, 1997).

Over time, Civil Protecion Planning has taken the form of a collection of different activities used to protect populations from both man-made and natural disasters (Alexander, 2002). Modern civil protection and related planning, which emerged from 'civil defense' practices, has focused on managing populations, primarily through a top-down authoritarian approach. It has moved beyond command and control practices, drawing rather from practices of information sharing, collaboration, and distributed efforts among responsible organizations. This is also seen in the European Union, which focuses on processes, civil protection mechanisms rather than planning (Prior et al., 2016). Thus, planning is devolved to the member states, with no real cross-border coordination.

In Italy, in 2018 came into force the new Italian Civil Protection Code, the Legislative Decree n. 1 of 2018 - DLgs 1/2018 (CPC, 2018), which aims both to simplify and coordinate all civil protection activities, and to ensure an operation, in the emergency phase, linear, effective and timely.

In particular, art. 2 describes all the structural and non-structural Civil Protection activities. The structural activities are those related to the definition of guidelines for prevention policies, programming and execution of interventions aimed at the mitigation of natural risks or arising from human activity. Among the non-structural activities there are alerting, training, communication and information and there is also the planning of civil protection, that is the set of non-structural prevention activities, based on forecasting activities and, in particular, on the identification of scenarios, with the aim of:

- to the definition of operational strategies and model of intervention in relation to the optimal areas;
- to ensure the necessary information link with the structures in charge of alerting the National Service;
- to the definition of communication flows between the components and operational structures of the National Service concerned;
- the definition of mechanisms and procedures for the revision and updating of planning, for the organization of exercises and for the information to the population, to be ensured also during the event. (art. 18; CPC, 2018).

The Civil Protection planning process, as defined by DLgs 1/2018 (art. 18), also includes:

- the participation of citizens, individual or associated, in the process of drawing up the plan;
- the coordination of civil protection plans with the plans and programs of management and protection and rehabilitation of the territory and the other sphere of strategic territorial planning;
- the integration between the various civil protection systems of the different territories.

The coordination of the Civil Protection Plan with the plans of management and protection and rehabilitation of the territory, as well as with the territorial strategic ones, underlines the importance of the Knowledge System (Di Ludovico & Fabietti, 2017) that is the basis of planning, in particular the knowledge of risks (multi-risks). In fact, the Knowledge System can be seen as the result of a continuous and dynamic technical-scientific action, whose structure must necessarily be flexible in order to collect and analyse data and information concerning issues, risks, that are constantly changing. A Risk Knowledge System can only be thought of as a dynamic system. This aspect requires that the civil protection planning, but also the coordinated territorial, environmental and landscape planning, acquire the character of flexibility (Di Ludovico, 2017).

Therefore, also for the Regional Management Risk Plan, as part of a broader Civil Protection Plan, the Knowledge System assumes a primary role, from which it is possible to deduce the Risk Scenarios and define prevention actions and mitigation projects, thus allowing the RMRP to acquire a function that straddles the structural (risk mitigation) and non-structural (risk prevention) functions of civil protection.

Section 2 describes the experience conducted in scientific research on the construction of a Knowledge System for civil protection planning and in particular for a Regional Management Risk Plan in which the theme of risk in its various components (Hazard, Vulnerability, Exposure) is central. Section 3 briefly defines the contents of the Regional Management Risk Plan. The article closes with a section on conclusions.

2. Knowledge for civil protection planning

As seen in the introduction, the Civil Protection planning process defined by the DLgs 1/2018 (art. 18), provides that the same is coordinated with the planning and programming of management and protection and rehabilitation of the territory and the other sphere of territorial strategic planning. This coordination emphasizes the importance of a fundamental component common to all planning processes, namely the Knowledge System, which can be considered the first tool for integration between the same processes. It has also been emphasized that the Knowledge System can be seen as the result of a continuous and dynamic technical-scientific action, whose structure must necessarily be flexible in order to collect and analyse data and information concerning issues, risks, that are constantly changing (Di Ludovico, 2017). This is the model of Knowledge System to which the research refers, that is an open, dynamic, modifiable, socially shared system, integrated in the different planning processes that affect the territory (multi-sectoral and multi-level), first of all that of civil protection and specifically of multi-risk management. To such a Knowledge System must correspond a planning model that is also dynamic and updatable, therefore flexible, directly connected to the Knowledge System.

Such a Knowledge System has already had a first experimentation in the 'Carta dei Luoghi e dei Paesaggi' (Map of Places and Landscapes) (Properzi et al., 2014), published in the WebGis of the Abruzzo Region under the name of 'Sistema delle Conoscenze Condivise' (Shared Knowledge System) to support the new Landscape Plan. It is a complex GIS that describes the territorial, environmental and landscape components through the categories of Values, Risks, Degradation and Abandonment, Urban and Territorial Framework, and Constraints. These derive from (1) institutional knowledge, produced at different scales by entities such as Regions, Provinces, Municipalities and many others; (2) local or identity knowledge outcomes of the knowledge sharing phase by organized groups of citizens, associations and other organizations; (3) intentional or project knowledge, inferred from the specialized analyses produced within the planning/design phase (Di Ludovico, 2017). Such a system, unveiling all the knowledge of a territory (this aspect is related to the concept of 'veil of ignorance' theorized by John Ralws and to the justificationist attitude of planning), can be considered the basis of planning processes of any level and sector, but it is also oriented to assume the role of a tool for the preliminary environmental compatibility evaluation of the choices made on urban and spatial plans and projects (Di Lodovico & Di Ludovico, 2014). Of these components, our research specifically explores the Risks.

In a parallel research to the one presented in this paper, a Digital Platform (Antofie, Doherty & Marin Ferrer, 2018; Weinberger, 2012) based on the new concept of Spatial Information Modeling (SIM), evolution of City Information Modeling (CIM), is being studied in relation to the specific theme of risks, which the present research program is developing (Di Lodovico & Di Ludovico, 2017; Xu et al., 2014). The platform aims to integrate institutional/scientific Knowledge, with intentional/project and local/identity Knowledge (Di Ludovico, 2017), thus overcoming self-referential meanings of the same Knowledge, promoting a new way of doing governance, but above all ensuring the coherence, i.e. the alignment and adjustment, of plans and decision-making system of local, regional and central administrations in terms of civil protection and risk mitigation (Properzi et al., 2014). In fact, its main feature is to connect, in a circular logic, Knowledge, Governance and Plan/Project.

2.1 The Knowledge System of the Civil Protection Plan of the Abruzzo Region

The topic of knowledge has always played a central function in the disciplinary debate, particularly with respect to the role it plays in the urban and territorial planning process, a role that is often secondary or justificationist (Di Ludovico, 2017). Instead, the knowledge factors of risk, which are typically multidisciplinary and multi-scale, should take a main role in the planning process and the latter should refer to a model that puts in the foreground the effects and mitigation of the same risks (Properzi et al., 2014). As already described in the previous paragraphs, the Government of the Territory is a complex (territorial, environmental, economic, social and landscape) and wide area of interest, where are also included patterns of use, perspectives and visual relationships, social and cultural practices, economic processes, relevant historical-cultural, natural-environmental and landscape values, exposed to hazard. It is essential, in this perspective, to systematize and update the regional and national knowledge frameworks, paying particular attention to the issue of risk, mitigation of effects and increasing territorial security (Di Lodovico & Di Ludovico, 2017).
Starting from these reflections, and taking into account the most relevant risks for civil protection purposes (Art. 16 and 18; CPC, 2018), in the research a model of the Knowledge System of the Abruzzo Region Civil Protection Plan was developed and tested. A knowledge system that addresses in particular the issue of multi-risks, in addition to the knowledge analysis of the municipal territory, namely the knowledge and consequently the in-depth analysis of seismic, hydraulic, hydrogeological risk, from adverse weather phenomena or for dam risk, snow and avalanches, forest fires, water deficit and seaquake. The volcanic risk has not been examined because it is absent at territorial level. However, it must be remembered that the Abruzzo Region is involved in the emergency procedures in case of eruption of Vesuvius or the Campi Flegrei area (Naples city area). The other types of risk to be considered, i.e. chemical, industrial, transport, environmental and hygienic-sanitary, have been treated compatibly with the competences of the subjects institutionally in charge.

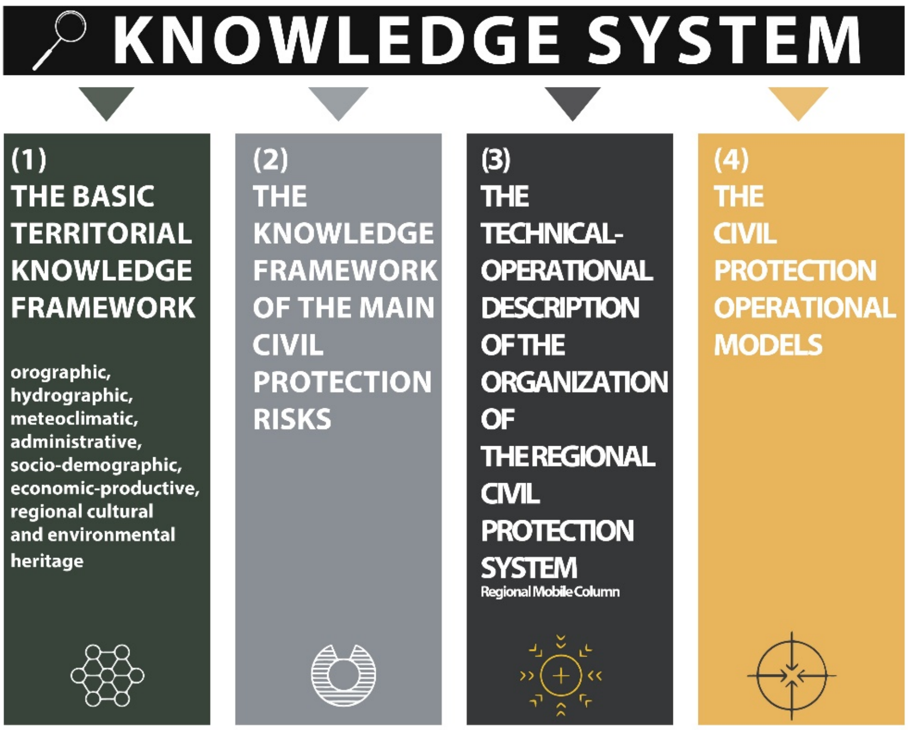

Fig.1 Outline of the Knowledge System of the Regional Civil Protection Plan

The above mentioned Knowledge System (KS) has been prepared in a specific research product (University of L'Aquila / Abruzzo Region) called 'Elementi conoscitivi del territorio della Regione Abruzzo e organizzazione di protezione civile' (Knowledge elements of the Abruzzo Region territory and civil protection organization of the Abruzzo Region (It); RegAbr, 2019). This specific report describes a dynamic and updatable structure of the KS (Fig. 1), and it has been drafted starting from the assumption that the knowledge of the territory is the essential requirement for a correct Civil Protection planning (Di Ludovico & Di Lodovico, 2019; Di Ludovico, 2017; Properzi et al., 2014).

The KS consists of four elements. (1) the basic territorial knowledge framework (orographic, hydrographic, meteoclimatic, administrative, socio-demographic, economic-productive, regional cultural and environmental heritage); (2) the knowledge framework of the main civil protection risks; (3) the technical-operational description of the organization of the regional Civil Protection system, the composition and the intervention model of the Regional Mobile Column; (4) the Civil Protection operational models.

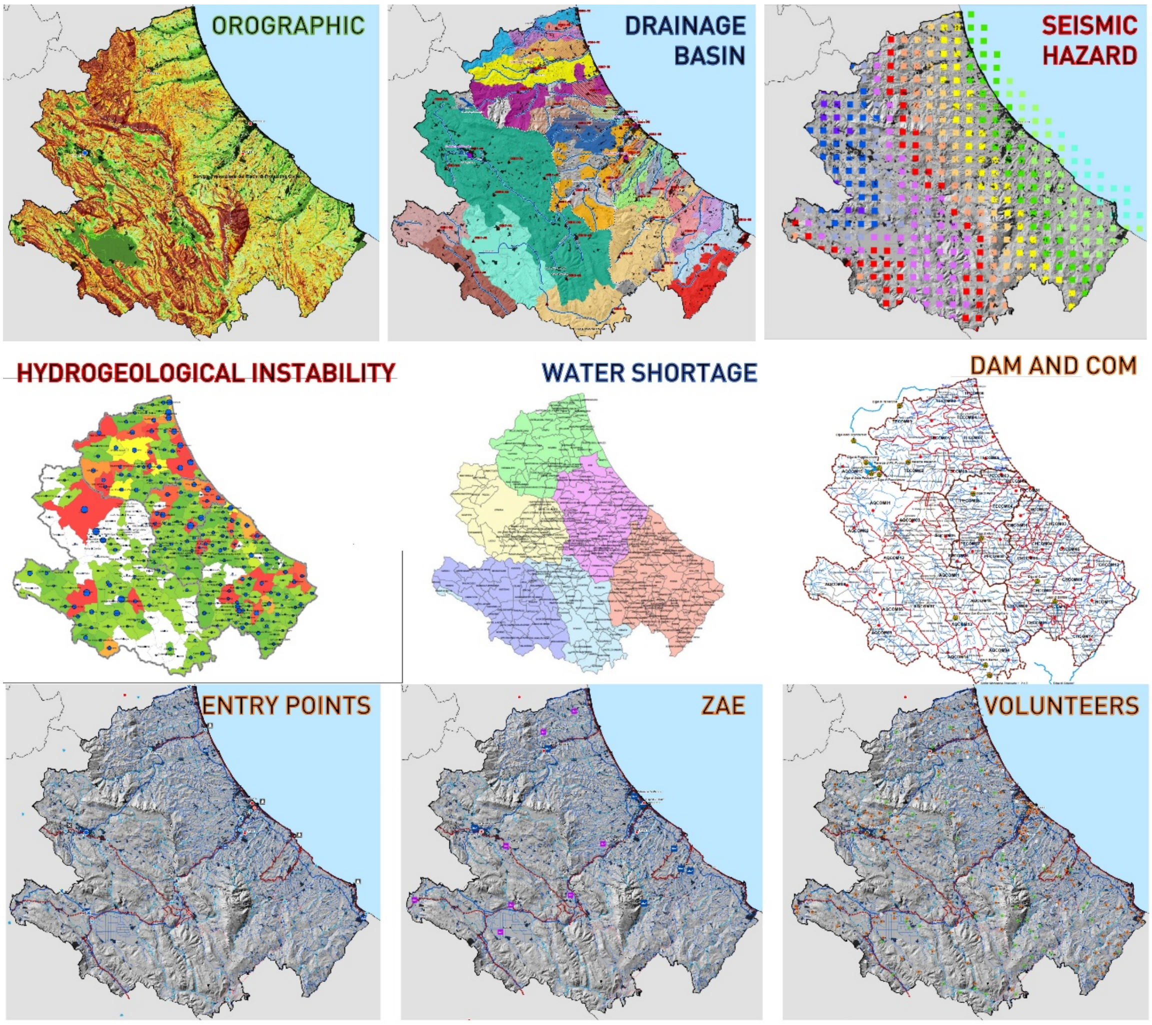

Fig.2 Some examples of GIS maps of the Knowledge System of the Regional Civil Protection Plan, as the basis of a digital platform for Spatial Information Modeling

Among the information collected for the KS, the data collected during the reconstruction phase of the post Abruzzo 2009 earthquake have been fundamental, allowing the production of completely new knowledge bases that represent innovative elements to support the analysis of risk components. For example, these are the following georeferenced databases (Fig. 2):

- schools (cover the whole Region), which includes data related to their geometric characteristics, Peak Ground Acceleration (PGA) data and related damages, when present. This is an update of the database available on the website of the Abruzzo Region[1] in the section 'School Buildings Information System' (SIES). The updating of the database was carried out in collaboration with the 'Network of University Laboratories of Earthquake Engineering' (ReLUIS) and the Special Office for the Reconstruction of the Crater (USRC)[2];

- the complete census of all strategic structures for civil protection can also be consulted online on the website of the Regional Civil Protection[3], in the section 'Sistema Informativo Edifici Strategici' (Strategic Buildings Information System - SIGEOIS);
- the mosaic of Seismic Microzonation Studies (MzS) and the Emergency Limit Condition (CLE), still in preparation for the entire regional territory, which represents a thorough reading of local seismic conditions and therefore a fundamental tool to identify more accurately the vulnerabilities (Di Lodovico & Di Ludovico, 2018);
- the complete census, updated to 2019, of 18,000 phenomena of hydrogeological instability present on the Regional territory (65 slopes conspicuously affected by deep gravitational deformations; 186 bodies of landslides of collapse and overturning; 727 bodies of landslides of translational sliding; 3,512 rotational sliding landslide bodies; 1,953 subsidence landslide bodies; 412 landslide bodies of complex genesis; 6,510 slopes affected by slow surface deformation and surfaces with diffuse and/or concentrated forms of runoff; 1,446 gully surfaces and similar forms);
- the regional map of the location and characterization of dams, weirs and crosspieces in the region with subdivision of the reservoirs according to their authorization and supervision;
- the map of the regional hydrographic basins with indication of the Territorial Presidiums and COMs (Mixed Operational Center);
- the map of the regional health system with indication of the Hospitals and Health Centers;
- the map of fire danger with an indication, in percentage, of the forest types classified according to the level of danger;
- the Synthetic Framework of the characteristics of the regional water supply system (divided into 6 sub-areas), built with information taken from the Emergency Management Plans submitted by the Managers of the Integrated Water Service;
- the Synthetic Framework and the database of all the State Operational Structures to be involved in an emergency and for rescue and/or relief operations (VV.FF., Red Cross, Carabinieri, Port Authority, etc).

These are often autonomous GIS or Databases, which have been integrated into the KS, addressing issues of thematic, temporal and scale coherence. The objective, that the research dedicates to the construction of this first KS is to devise a digital platform of knowledge for the establishment of a planning tool called Spatial Information Modeling (SIM), aimed at the analysis and governance of risks, support of Prevention Projects and Territorial Recovery (Section 3), and place of integration of civil protection planning with the urban and spatial, pursuing an approach that at the international level is referred to as comprehensive (cite).

Such a Platform is composed of three components: information (of various types, bases for analytical application to support innovative planning tools), communication/participation (with various tools and techniques) and governance of the plan/project (the innovative tools verified through the basic information). Its main objective is on the one hand to constitute the autonomous Knowledge System from information, and on the other hand to generate and evaluate models and frameworks of territories and cities, to understand and represent their processes, to support their debate and address their conflicts. The Knowledge System and

1 http://protezionecivile.regione.abruzzo.it/index.php/rischio-sismico

2 DPC-ReLUIS 2019-21 Project, WP4-MARS (Task 4.7 – "Modelli e curve di fragilità per le scuole e altri edifici strategici o rilevanti").

3 http://protezionecivile.regione.abruzzo.it/index.php/rischio-sismico

these frameworks can show events in progress, those that took place in the past that will take place in the future, through two-dimensional techniques, scenarios, diagrams, ideograms, etc. (Hanzl 2007, p. 290).

3. From the Knowledge System of the Regional Civil Protection Plan to the Regional Management Risk Plan

The constitution of the Knowledge System of the Abruzzo Region Civil Protection Plan was the starting point for the construction of a part of the Civil Protection Plan dedicated to multi-hazard analysis, prevention and mitigation/reduction of risks, the so-called 'Regional Management Risk Plan' (RMRP) that responds to the demand for prevention and mitigation typical of 'structural' civil protection activities (Di Ludovico & Di Lodovico, 2020).

The topic of Disaster Risk Management (DRM) is becoming more and more central in the context of Spatial Planning (Poljanšek, Marin Ferrer, De Groeve & Clark, 2017). In this context, the experimentation of the RMRP of the Abruzzo Region (within the Civil Protection) addresses the issue of Multi-Risk (Gallina et al., 2016) by structuring a methodology oriented to prevention planning, with a focus on spatial aspects, rather than to emergency interventions implemented after the disaster.

Fig.3 Methodology of the Risk Management Plan of the Abruzzo Region

The proposed RMRP is based on an 'all hazards at a place' approach (Hewitt & Burton, 1971), and has as its ultimate goal the identification of 'Prevention and Spatial Recovery Projects' (PSRP). These projects represent the tools for implementing prevention/mitigation and recovery actions, and the tools for coordination (Rivera, Tehler & Wamsler, 2015) between these actions and those provided by other levels of Planning unrelated to Civil Protection but impacting the territory, environment and regional landscape.
The RMRP of the Abruzzo Region is based on a detailed Knowledge System, described in Section 2 above, which undergoes a Multi-Risk Assessment process (Risk Mapping → Assessment → Planning (FEMA, 2018)), which crosses the components of Multi-Hazards (M-H), Multi-Vulnerability (M-V), and Multi-Exposure (M-E) (Fig.3).
These three knowledge components have been selectively crossed according to an innovative methodology in order to obtain the Risk Scenarios, which have been differentiated into two large groups, those involving the Environmental/Landscape system and those involving the Anthropic/Settlement system. The identification of Risk Scenarios allows for the selection of risk treatment options, a subject explored in both the defense and financial fields, for example with the ACAT - Avoid / Control / Accept / Transfer model (DoD, 2017), or the TARA - Transfer / Avoid / Reduce / Accept model (Kaplan, 2012).
The Risk Scenarios correspond to the planning of two actions, one involving Prevention interventions and another involving Mitigation interventions and therefore Risk Control. In our methodology these actions have been differentiated also according to the main classes of land use, namely natural / semi-natural use, urban use and agricultural use.
The subsequent selective overlay of the Risk Scenarios has allowed the identification of the so-called 'Hotspots' (Fig. 4), big multi-risk 'hot' areas, with high priority in which there are more high risks, and in which it is foreseen to intervene with specific planning instruments, the already mentioned 'Territorial Prevention and Recovery Projects' (Fig. 5.1 & 5.2) that foresee spatial interventions of prevention/mitigation and recovery with low impact and coherent with the objectives and strategies of the other levels and types of Plans present in the same areas.
This process allows to improve the balance of development requests with the need to protect the environment and the landscape, that is, risk mitigation, and coordination of the spatial impacts of prevention and mitigation interventions with territorial policies.

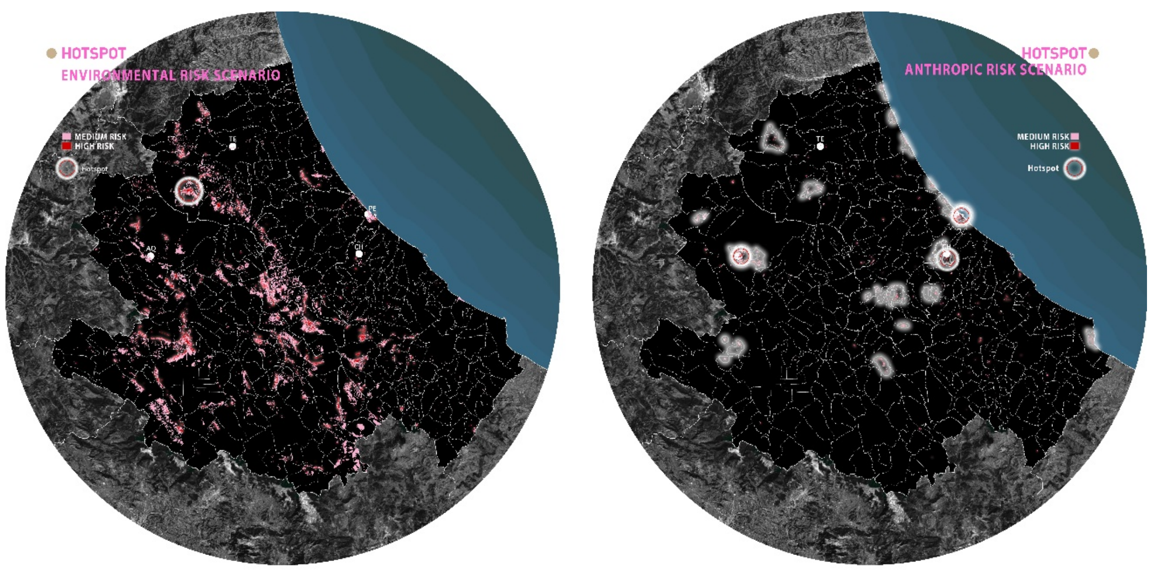

Fig.4 The Multi-Risk Hotspots in the Regional Management Risk Plan (Source: Elena Scarpone). The white circles identify the Hotspots in which the PSRPs have been tested

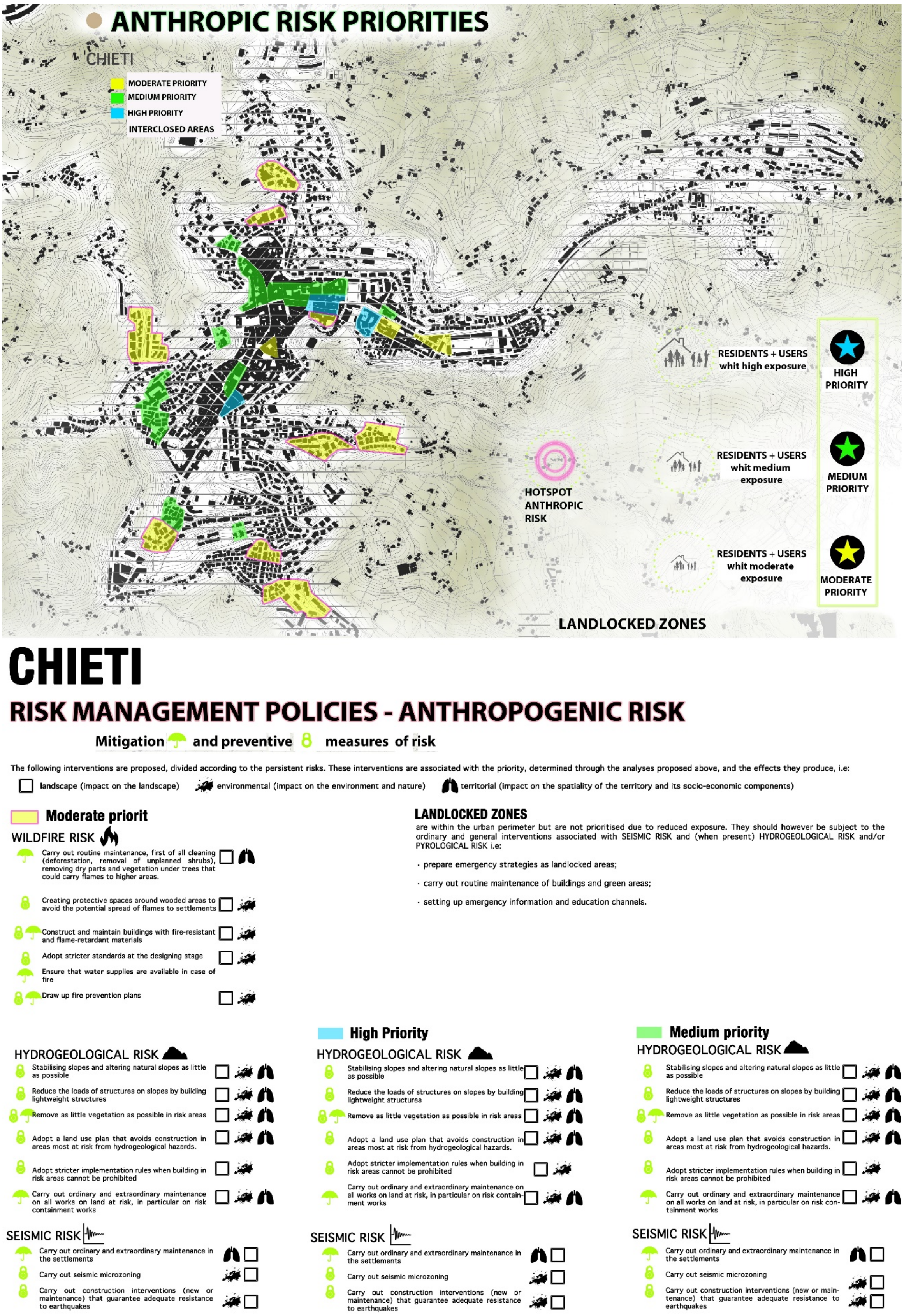

Fig.5.1 Example of Prevention and Territorial Recovery Projects in a settlement Multi-Risk Hotspot (Source: Elena Scarpone)

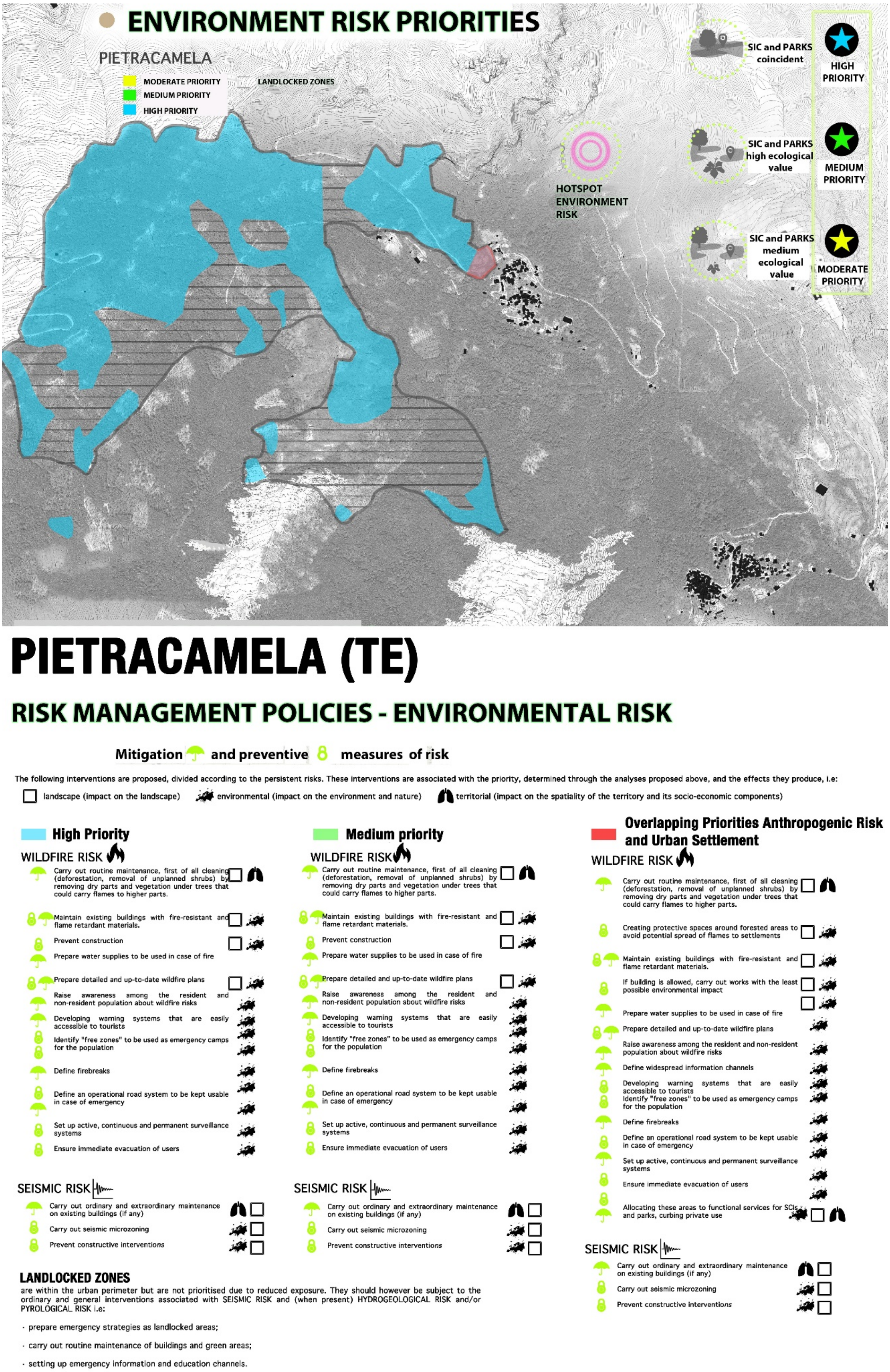

Fig.5.2 Example of Prevention and Territorial Recovery Projects in a Multi-Risk Hotspots located in vulnerable area of environmental value (Source: Elena Scarpone)

The result is a complex work, still in progress, that will be integrated in the new research of the project 'Territori Aperti'[4] (Open Territories) of the University of L'Aquila. This project, now in its early stages, aims to bring together data, knowledge and work for the progress of areas affected by natural disasters. It provides for the creation of an 'Interdisciplinary Center for Documentation, Training and Research' oriented to the prevention and management of natural disasters and to the reconstruction and development of the affected areas. In particular, the project foresees the constitution of an Integrated Information System open to social sharing, the realization of training and communication activities, and the realization of research activities oriented to the creation of an international network of competences on the sustainable development of the territories affected by natural disasters.

4. Conclusions

The scientific research described in this paper concerns the theme of Civil Protection Planning at Regional level, and in particular the role that its Knowledge System can assume when dealing with Disaster Risk Management at Regional level whose planning can be considered a part of Civil Protection Planning.
The model of the Knowledge System to which the research refers, which has been experimented in the definition and predisposition of the 'Knowledge elements of the Abruzzo Region territory and civil protection organization of the Abruzzo Region (It)', is the result of a continuous and dynamic technical-scientific action, whose structure must necessarily be flexible in order to collect and analyse data and information concerning themes, the risks, which are constantly changing. Such a model of Knowledge System, which can be managed through a digital platform in the form of Spatial Information Modeling (SIM), requires that the civil protection planning but also the coordinated territorial, environmental and landscape planning acquire the character of flexibility, and this feature is one of the main limitations of the proposal as it presupposes a radical change in the current Italian planning systems and models that are extremely rigid and stable, rather than flexible and dynamic.
In the research, the Knowledge System has become the basis for the experimentation of a methodology for a Regional Management Risk Plan (case study Abruzzo Region), faced with an original hybrid approach, simultaneously evaluative and spatial/structural. The methodology uses the concept of Multi-Risk, analyzed with a semi-quantitative approach, to identify Hotspots, i.e. areas characterized by very high and probably simultaneous risks, in which it is strictly necessary to identify prevention and mitigation interventions, the 'Territorial Prevention and Recovery Projects' (PSRPs) that concern the structural activities of civil protection. The PSRPs also represent the interface with the planning of management and protection and rehabilitation of the territory and the other areas of strategic territorial planning, defined as non-structural activities of civil protection. The research has shown that the Knowledge System can facilitate the integration between different levels and sectors of planning, but that this operation is strongly hindered by the conformative and regulatory nature of Italian planning.
The next steps of this research foresee the construction of the Digital Platform of Knowledge for the constitution of the Spatial Information Modeling (SIM) aimed at the analysis and governance of Risks, support of Prevention and Territorial Recovery Projects (PSRPs), and place of integration of Civil Protection planning with the urban and spatial, pursuing an approach that is internationally referred to as comprehensive.

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Image Sources

Fig.1: Luana Di Lodovico, Donato Di Ludovico;

Fig.2: RegAbr, 2019;

Fig.3: Luana Di Lodovico, Donato Di Ludovico;

Fig.4: Elena Scarpone;

Fig.5.1: Elena Scarpone;

Fig.5.2: Elena Scarpone.

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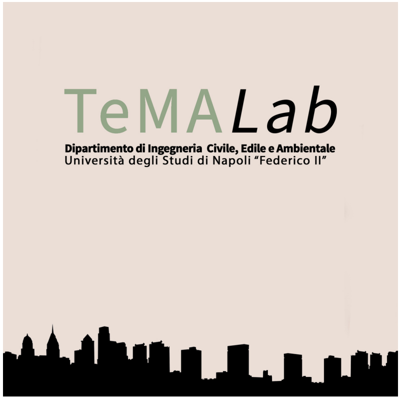

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Climate change as stressor in rural areas

Vulnerability assessment on the agricultural sector

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Abstract

This research aims at identifying main risk factors on rural areas, investigating characteristics both of the stressor and of the system, providing ordinary planning with tools that are useful in a preventive perspective and not only in emergency conditions. Local vulnerability assessment is a key tool able to provide a framework for prioritizing choices and actions in different strategies and policies. In literature, many studies focus on the assessment of local vulnerability, but there are few directly site-specific methods concerning climate change as stressor in rural areas, although they are particularly vulnerable contexts to climate change. Vulnerability of rural areas is principally linked to their significant dependence on agriculture sector and to specific socio-economic dynamics, often responsible of inequalities within communities.
Starting from these assumptions, authors define a methodology to quantitatively assess, in rural areas, the level of vulnerability to climate change based on climatic and context analysis at the municipality scale. The methodology is based on numerical and statistical computation operations on a set of indices of climate exposure, sensitivity and adaptive capacity in order to provide an aggregate Vulnerability Index. The paper presents the results of the application to the Calabrian territorial context of the Grecanica Area (Italy).

Keywords

Climate change; Vulnerability; Rural areas; Agricultural sector.

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1. Introduction

Urban planning is called to face multiple risks: they range from natural hazard-induced disasters to socio-economic crisis (Renn at al., 2018). In the last decades national and supranational governments are adopting tools and strategies able to manage an unexpected emergency and, only more recently, aiming at mitigating negative effects of an event through a preventive planning. But often, these policy instruments follow separate approaches and never interface each other, with an even more insidious problem: they have no adequate join with ordinary tools responsible to territorial transformations.

With special refer to Italian case, Emergency Plan is already considered as just an operational and rescue management tool that, in most cases, doesn't provide appropriate assessments regarding preventive strategies of risk mitigation. It could be considered inadequate for elaborating vulnerability, hazard, and exposure maps[1], because it merely transposes the indications of higher-level tools without an appropriate change of scale which, with more detailed assessments, would probably allow to reach different conclusions. The coordination among sector tools and ordinary planning, where present, is often unidirectional or limited to binding character: the Hydrogeological Plan, for example, identifies areas at risk with the only main objective to establish precise limitations in land use; other specialist reports (such as geological ones) born as support of ordinary plans, remain still today a separate part of the overall planning process (Menoni, 2006). It is also important to point out that the Emergency Plan doesn't consider directly risks related to climate change. In the European context, on the other hand, the Sustainable Energy and Climate Action Plan (SECAP) contains specific references to the assessment of vulnerability to climate change considering different types of risk (flood, landslide, erosion). The implementation of the SECAP favored by the Covenant of Mayors for Climate and Energy sees European cities committed to reducing their CO2 emissions and increasing urban resilience by adapting to the effects of climate change.

Moreover, it's worth to specify that the variety of risks is not only linked to their typology, but also to their spatial and temporal dimensions. With reference to first aspect, every risk mitigation strategy should be implemented from a site-specific knowledge framework, able to identify both the scale of application and the characteristics of the area where a type of risk acts. From a temporal point of view, effective mitigation strategies should take into account the not-ordinary nature of disasters, but also how the natural evolution of the territory affects the ordinary dimension. Just think of those phenomena that generate slow but linear (and often disruptive) changes on the territory that Brunetta & Salata (2019) identify, for example, in land consumption, erosion and, especially, in climate change.

Starting from these assumptions and following a site-specific view, this research aims at identifying main risk factors on rural areas, investigating characteristics both of the stressor and of the system, providing ordinary planning with tools that are useful in a preventive perspective and not only in emergency conditions. Rural areas are characterized by their social, economic and environmental diversity. Frequently they suffer from the

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[1] The definitions of vulnerability, hazard, exposure, and risk to which we will refer in this paper are the following (Pachauri et al., 2014):

- Vulnerability: the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt;
- Hazard: the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts;
- Exposure: the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected;
- Risk: the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. In this report, the term risk is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure.

social point of view of rural exodus and the aging of the population, from the economic point of view of a high rate of poverty and from dependence on agriculture as the main productive sector and from the environmental point of view of natural risks (geophysical, meteorological, hydrological and climatic). Pagliacci (2017), highlighting the link between rurality and periphery and between hydro-geological and seismic hazards in Italy, has shown that the areas with high landslide hazard in rural municipalities represent 85% of the total risk areas and that inland areas (the most peripheral Italian municipalities) are more exposed than the national average to landslides and seismic events in terms of surface and population. Furthermore, agricultural activity, can suffer the effects of catastrophic events more than other activities, given its dispersion over the territory (Pagliacci & Bertolini, 2016). With respect to this condition, it has been recognized (Yasuhara et al., 2015; Gasparri & Iraldo, 2020; Islam et al., 2020) how climate change increases direct risks such as floods, storms, droughts, and sea storms that are increasingly frequent and higher intensity. In order to address these issues, the development of rural policies should first of all incorporate the different specific characteristics of rural areas through a territorial and multisectoral approach.

Based on related works (Section 2), this paper proposes a methodology (Section 3) aimed at quantifying the municipal vulnerability to climate change focusing on the agricultural sector through a multidimensional approach that combines climatic and contextual factors (environmental and socio-economic) with respect to climatic exposure, sensitivity and adaptive capacity. The results of the application of the methodology on a territorial context of southern Italy (Section 4), intend to suggest useful considerations both to verify the integration of mitigation measures to climate change in planning and to evaluate which tools and strategies can increase the resilience of the territories (Section 5).

2. Related works

Climate change is a large-scale challenge (Papa et al., 2015) and the need to define consequential adaptation measures is internationally recognized (Zucaro & Morosini, 2018). This is confirmed by the adoption in 2015 of the Sendai Framework for Disaster Risk Reduction and the Paris Agreement on climate change which support national and supranational strategies in increasing coherence[2] in the approaches to Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) planning. OECD (2020) defines a set of opportunities for achieving greater coherence in CCA and DRR including put further emphasis on generating comprehensive information related to current vulnerability to make tailored climate information readily available to support "evidence-based" policies. In fact, the effects induced by the climate are diversified in local contexts according to the physical and natural condition, the socio-economic development and the adaptability that characterizes them and local instruments and policies do not always take them into account. Local vulnerability studies with focus on thematic areas oriented to priority evidence can reduce this gap strengthening their resilience (Galderisi & Ferrara, 2012). The thematic focus that will be explored is represented by the agricultural sector for rural areas. In fact, the agricultural sector suffers the effects of climate change in terms of productivity and food security (Caserini, 2015) due to frequent phenomena in southern Europe such as extreme heat waves and the reduction of rainfall and water resource (Kelemen et al., 2009). Increasing awareness of weather instability is essential in order not to run the risk, for example, that farmers adopt management solutions with a greater impact on less protected natural resources and abandoning areas more exposed to instability, favouring the processes of degradation and desertification (Calvitti et al., 2016).

The impacts of climate change can be broadly grouped under three headings: ecological, social, and economic. The ecological impacts of climate change include shifts of vegetation types and associated impacts on

2 The advantages of greater coherence between the two policy approaches are manifold, especially in virtue of the close correlation among the effects of climate change and natural risks, which should be implemented in local development strategies and policies. However, to further guide decisions on CCA and DRR, climate data should be supplemented with information on other ecological, economic and social factors affecting local vulnerability.

biodiversity; change in forest density and agricultural production; expansion of arid land; decline in water quantity and quality; and stresses from pests, diseases, and wildfire. Salient social impacts may include changes in employment, equity, risk distribution, and human health, and relocations of populations. Economic impacts include increased risk and uncertainty of forest or agricultural production, alteration in productivity for crops and forest products, reduction in supply of ecosystem goods and services, increased cost of utilities and services, and altered energy needs (Alavalapati et al., 2011). These three headings of impacts assume particular relevance in rural areas. Thus, site-specific methods of assessment are required to assess the levels of vulnerability to human communities due to multiple driving forces in relation to specific outcomes (Adger & Vincent, 2005; Pandey & Jha, 2012). The vulnerability of agricultural sector to climate change varies according to exposure to adverse climatic conditions and the socio-economic context. In particular, socio-economic factors determining resilience are among other things: characteristics of farms, such as type of production, size and level of intensity; diversity of cultivation and livestock systems, presence of other sources of income external to agriculture; access to useful information, skills and knowledge of climate trends and adaptive solutions; the role played by advisory services in facilitating adaptation; general socio-economic situation, particular vulnerability of farmers with limited resources or established in particularly remote rural areas; access to available technologies and infrastructure capacity (Parker et al., 2019; Kantamaneni at al., 2020; Seif-Ennasr et al., 2020; Ju et al., 2020). The unequal effects of climate change could accentuate regional differences and exacerbate economic disparities. In the long term, climatic pressures could lead to further marginalization of agriculture or even the abandonment of agricultural land in certain parts of the Europe.

The literature provides many definitions of vulnerability describing its components and conceptual frameworks that give mining to the definition and can be analysed according to the analytical context in a transparent and repeatable way (Nelson et al., 2010). The Intergovernmental Panel on Climate Change (IPCC) describes vulnerability as "the degree of susceptibility or incapacity of a system to face the adverse effects on climate change" (Pachauri et al., 2014), also including variability and extreme events. It assumes that vulnerability is a function of three dimensions that are exposure of a system, its sensitivity and its adaptive capacity.

A commonly used quantitative approach is the construction of a vulnerability index starting from specific sets or combinations of indicators (Gbetibouo et al., 2010; Monterroso et al., 2014). In order to define the methodology, we analysed some studies proposed in the literature. Tab. 1 shows the main results.

These studies show how vulnerability is context-specific, and the factors that make a system vulnerable to the effects of climate change depend on the nature of the system and the type of effect in question (Brooks et al., 2005).

3. Methodology

This research is aimed at proposing a new methodology, based on an index approach, able to assess vulnerability to climate change in rural areas and to evaluate how the current strategies and policies treat this issue. This study follows the definition of vulnerability adopted by the IPCC (Pachauri et al., 2014). According to this definition, the research treats agricultural sector as the vulnerable system and climate change as the stressor (Wiréhn et al., 2015) through two different type of analyses:

- Climatic analysis, linked to the stressor and thus to the exposure of the system;
- Context analysis, linked to the characteristics of the system itself that, being specifically a rural area as anticipated, will deal with special refer to agricultural sector and to socio-economic features of the area.

The choice of combining analysis derives from some literature studies aimed at providing different interpretation of vulnerability: the outcome vulnerability, principally focused on information about potential climate impacts (exposure of a system) and the contextual vulnerability, rooted on internal characteristics of the vulnerable system or community that determine its propensity to harm for hazards (O'Brien et al., 2007; Füssel, 2010).

If researchers and administrators didn't act to properly combine these two different approaches they, taken individually, could produce very different ranking of vulnerable regions and tend to choose or technological solutions to minimize particular impacts or the reliance exclusively on response capacity of a community. This strict choice could affect system worse than vulnerability itself.

Study name	Dimensions and Assessment outputs
Assessment of composite index method for agricultural vulnerability to climate change (Wiréhn et al., 2015)	System of interest: Swedish agricultural productivity; Spatial scale: Municipal level Main biophysical aspects considered: temperature and precipitation information, crop diversification, erosion risk, soil characteristics; Main socio-economic aspects considered: population density, unemployment rate, social welfare payments, farm holding size and income; Methods and tools: Vulnerability index is based on standardisation of data and PCA to generate weights; Presentation of results: Use of narratives, maps, tables.
Vulnerability of the South African farming sector to climate change and variability: An indicator approach (Gbetibouo et al., 2010)	System of interest: South African farming sector; Spatial scale: Provincial level; Main biophysical aspects considered: frequency of past climate extremes, predicted change in temperature and rainfall, irrigation rate, land degradation, crop diversification; Main socio-economic aspects considered: rural population density, social capital (literacy rate, HIV prevalence), human capital, financial capital (farm income, farm size, access to credit), physical capital (infrastructure); Methods and tools: Climate vulnerability indices are based on three different weightings and three different summarizing methods; Presentation of results: Use of narratives, maps, tables.
Two methods to assess vulnerability to climate change in the Mexican agricultural sector (Monterosso et al., 2014)	System of interest: Mexico's agricultural sector; Spatial scale: Municipal level; Main biophysical aspects considered: extreme events, environmental problems, climate, agriculture, natural capital; Main socio-economic aspects considered: human capital, social capital, financial capital; Methods and tools: Climate vulnerability indices are based on PCA and equal weights; Presentation of results: Use of narratives, maps, tables.
Climate vulnerability index – measure of climate change vulnerability to communities: a case of rural Lower Himalaa, India (Pandey & Jha, 2012)	System of interest: Vulnerability of rural communities in Himalaya; Spatial scale: District level; Main biophysical aspects considered: natural disaster and climate variability, health, food, water; Main socio-economic aspects considered: socio-demographic profile, livelihood strategies and social networks; Methods and tools: Aggregation of data undertaken from household questionnaire survey; Presentation of results: Use of narratives, tables and charts.
Vulnerability Assessment of Forest Fringe Villages of Madhya Pradesh, India for Planning Adaptation Strategies (Yadava & Sinha, 2020)	System of interest: Vulnerability of forest fringe villages of Madya Predesh, India; Spatial scale: District level; Main biophysical aspects considered: agriculture, energy, water access; Main socio-economic aspects considered: social class, economic class, level of education, occupation; Methods and tools: Aggregation through PRA of indicators chosen based on the review of the literature and a reconnaissance survey. Using of PCA for extraction the significant indicators and Varimax method for the rotation of the factors; Presentation of results: Use of narratives and tables.
Climate-drive vulnerability and risk perception: implications for climate change adaptation in rural Mexico (Michetti & Ghinoi, 2020)	System of interest: Vulnerability of rural communities located in Mexican lagoon; Spatial scale: Municipal level; Main biophysical aspects considered: identification of communities most affected by climate change according to micro-level statistics and census data; Main socio-economic aspects considered: working conditions, affiliation to cooperatives or other organized structures, family earnings, socio-political relations and beliefs, perceptions and knowledge; Methods and tools: Aggregation of data from results of structured survey; Presentation of results: Use of narratives, tables and charts.
The effect of spatial proximity to cities on rural vulnerability against flooding: an indicator-based approach (Jamshed et al., 2020)	System of interest: Vulnerability of rural farming communities against flood hazard in Pakistan; Spatial scale: Sub-district level; Main biophysical aspects considered: distance to water body, degree of loss/damage to standing crops, inadequate availability of water for farming, absence of safe drinking water; Main socio-economic aspects considered: physical dimension (distance to the nearest health facility, distance to paved road), human dimension (household head's education, Household accessing the market, weather and water-related information more frequently), social dimension (household living in the community, household accessing agriculture extension services more frequently), financial dimension (economic dependency ratio, household with more than one income source); Methods and tools: Aggregation of data from results of household survey through Mann-Whitney U and Pearson's correlation; Presentation of results: Use of narratives, tables and charts.

Tab.1 Review of related literature studies based on Carter & Mäkinen (2011) and Fellman (2012)

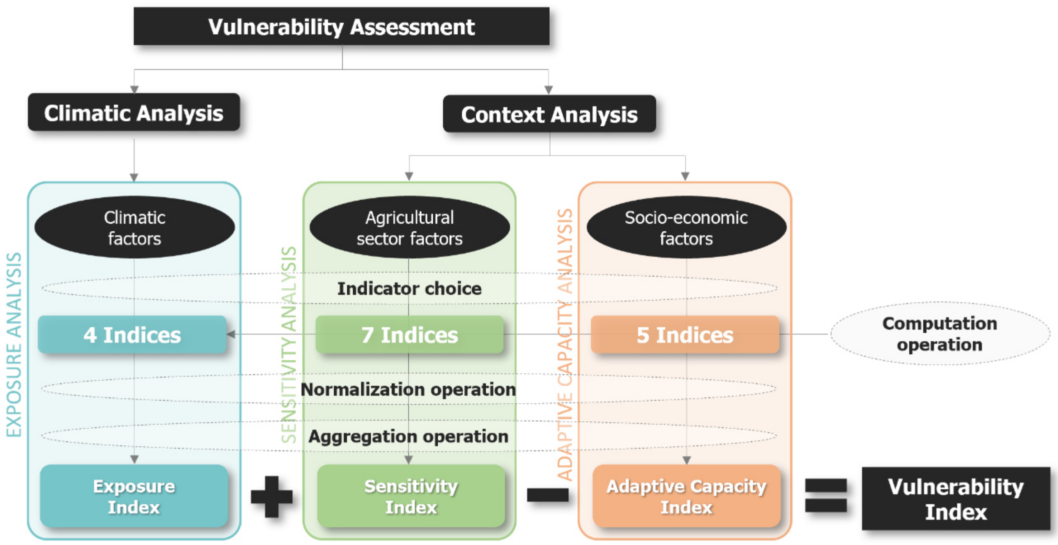

Fig.1 Methodology flow chart

The Fig.1 summarizes the methodology process that can be described into five steps:

- Index choice: a set of appropriate indices are chosen by the authors reworking and referring to the themes proposed by different literature studies in addition to those already provided in the previous section. Major details of this first methodological step will provide in following sub-paragraphs;
- Computation operation: each index is calculated at municipal scale through different procedures depending on whether is a climatic or context analysis. A geo-spatial database is populated trough a join algorithm among numerical and spatial data;
- Normalization operation: it is essential before any data aggregation to construct summary indices comparable both by each other – they often have different measurement units – and among single municipal results. This step is useful for understanding better the local vulnerability and its spatial distribution, for orienting policies toward a specific area or for identifying lands with urgent requirements. Currently, numerous methods of normalization exist (Freudenberg, 2003; Jacobs et al., 2004; Joint Research Centre-European Commission, 2008): for both analyses, the authors use min-max method that normalizes the measures to have an identical range (from 0 to 1) by subtracting the minimum value and dividing it by the range of the measured value.

$$x_{i,1} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \tag{1}$$

  In formula (1) x_i is the individual data to be transformed, x_{min} the lowest value for that index, x_{max} the highest value for that index and $x_{i,1}$ the normalized value: for every index, the minimum value of that feature gets transformed into a 0, the maximum value gets transformed into a 1 and every other value gets transformed into a decimal between 0 and 1.
- Aggregation operation: for each dimension, a synthetic index has to be defined.

$$DI_j = \frac{\sum_{i=1}^{n_j} w_i \cdot x_{i,1}}{n_j} \tag{2}$$

  Formula (2) allows the calculation of DI_j, the synthetic index for dimension j, by combining the normalized value of the indices $x_{i,1}$ previously weighted by associating the relative weight w_i; n_j is the total number of chosen indices for dimension j. Authors assign an equal weight to every index and calculate three final indexes through an aggregation procedure based on an arithmetic average.

It's worth to specify that is very important to pay attention to the direction of the index values. As described in following sections, authors define for each index a functional relationship able to express the contribution of the single index to the assessment of the analysed dimension: a positive relationship increases the value of the synthetic index I_j, a negative one decreases it;

- Calculation of Vulnerability Index: the last step consists in valuing vulnerability. Following previous assumptions, it could be defined as vulnerability to climate change assessed on agricultural sector in rural areas. Vulnerability Index VI depends on Climatic and Context Analyses and, particularly, it is a function of the three synthetic indices of exposure (EI), sensitivity (SI) and adaptive capacity (ACI), as express by formula (3).

$$VI = f(Climate\ Analysis, Context\ Analysis) = EI + SI - ACI \quad (3)$$

Particularly, exposure and sensitivity positively affect vulnerability, while adapting capacity is considered as a mitigating factor with a negative impact on vulnerability (Liu et al., 2013; Murthy et al., 2015; Michetti & Ghinoi, 2020).
Following two sub-paragraphs will describe into details the implementation of the first step of methodology both for climatic and context analysis.

3.1 Climatic Analysis

The climatic analysis is a fundamental prerequisite for assessing the impacts of climate change. The methodology considers the information relating to temperatures (Clim-1 and Clim-2), rainfall (Clim-3), and the risk of desertification (Clim-4) in order to evaluate the variations by observing the climatic variables and applying statistical methods and models of recognition and estimation of ongoing trends.

Code	Name	Definition	Functional Relationship[3]
Clim-1	Synthetic index of extremes of cold	Arithmetic average of standardization values of FD0, TR20, TNx, TNn, TN10p, TN90p4	+
Clim-2	Synthetic index of extremes of heat	Aritmetic average of standardization values of SU25, TXx, TXn, TX10p, TX90p, WSDI5	+
Clim-3	Synthetic index of the extremes of precipitation	Arithmetic average of standardization values of RX1day, Rx5day, R10, R20, R95p, SDII6	+
Clim-4	Territory at desertification risk	Percentage of dry soil surface between 86-159 days	+

Tab.2 Climate exposure index

In Tab.2 the Clim-1, Clim-2, and Clim-3 indices are the result of the aggregation of the indices defined among the most representative of the Italian climate by the Italian National Institute for Environmental Protection and Research (Alexander et al., 2006). As stated by the Expert Team on Climate Change Detection and Indices (ETCCDI) of the "CCL / CLIVAR Working Group on Climate Change Detection" (Peterson et al., 2001), they are suitable to describe the extremes of temperature and precipitation in terms of frequency, intensity and duration. These indices are divided into different categories.

[3] It expresses the contribution of the single indicator to increase (+) or decrease (-) exposure dimension.
[4] Considered indicators are:frost days (FD0), tropical nights (TR20), maximum value of daily minimum temperature (TNx), minimum value of daily minimum temperature (TNn), cold nights (TN10p), warm nights (TN90p).
[5] Considered indicators are:summer days (SU25), maximum value of daily maximum temperature (TXx), minimum value of daily maximum temperature (TXn), cold days (TX10p), wam days (TX90p), warm spell duration indicator (WSDI).
[6] Considered indicators are:maximum 1-day precipitation amount (RX1day), maximum 5-day precipitation amount (Rx5day), number of heavy precipitation days (R10), number of heavy precipitation days (R20), very wet days (R95p), simple daily intensity index (SDII).

Some indices are defined by a fixed threshold value, others are absolute indices, others are based on percentiles, and still others express duration (Francini et al., 2020). The methodology is therefore based on the elaboration of the data of the historical series of the minimum temperatures, the maximum temperatures and the daily accumulated precipitation recorded by the stations equipped with thermometer and rain gauge present in the study area and from the external ones no more than 15 km from the internal ones. For each hydrological series, in order to characterize and quantify the ability to provide reliable information, the parameters of continuity, completeness and quality defined by Braca et. al (2013) were calculated.

The continuity parameter ($C1$) is defined (4) so that a series that presents all valid data, equal to the maximum number of data, has a continuity index equal to 1 while, a series that presents valid data alternating with a missing data and which therefore has the maximum value of missing data intervals having value 0.

$$C1 = 1 - 2 * \frac{number\ of\ missing\ data\ intervals}{maximum\ number\ of\ data} \tag{4}$$

The completeness parameter ($C2$) provides (5) an indication of the number of valid data contained in the series with respect to the maximum totality of the data between the first and last detected value.

$$C2 = \frac{numer\ of\ valid\ data}{maximum\ number\ of\ data} \tag{5}$$

The quality of the series was assessed using the $iQuaSI$ index (6) based on the length of the series expressed in years and on the quality class of the single data.

The index varies between 0 and 1 and is defined as a linear combination of the ratios between the length of the part of the series consisting of data of a given quality class and the total length, with coefficients dependent on the length of the series.

$$iQuaSI = a_L * \left(\frac{L_A}{L}\right) + b_L * \left(\frac{L_B}{L}\right) + c_L * \left(\frac{L_C}{L}\right) + d_L * \left(\frac{L_D}{L}\right) \tag{6}$$

The methodology considers only the series characterized by maximum continuity and completeness parameters ($C1 = 1; C2 = 1$), as well as to exclude the series considered unusable ($iQuaSI \leq 0{,}10$).

The average value of the indices with respect to the series of historical data considered usable was associated with each station.

The Voronoi polygons were then constructed and the values of the indices for each municipality quantified as an average weighted on the areas of the Voronoi polygons influencing the municipality. Considering the last index, several literature studies identify drought as a potential hazard due to climate change with large negative impacts on agricultural sector (Wilhelmi & Wilhite, 2002; Liu et al., 2013; Murthy et al., 2015).

Starting from indications of a report of the General Directorate for Sustainable Development, Climate and Energy of Italian Ministry of Environment and Land and Sea Protection (2012) and following general goals of European project Region 2020 "*An Assessment of Future Challenges for EU Regions*", authors propose index Clim-4 in order to evaluate the exposure of the system to desertification risk.

3.2 Context Analysis

As anticipated, context analysis includes evaluations both on sensitivity of agricultural sector and on socio-economic features of the community able to increase or decrease the adaptive capacity.

Sensitivity refers to the degree of system response due to climate change. It is also the degree to which a system is potentially modified by a disturbance: human and environmental conditions can improve or worsen the impacts (Monterroso et al., 2014).

The proposed methodology inserts in this dimension some municipal indices able to describe the current state of the agricultural sector (Agr-1, Agr-2, Agr-3, Agr-4) and population (Pop-1, Pop-2) exposed to climate change (Tab. 3) (Jamshed et al., 2020; Yadava & Sinha, 2020; Žurovec et al., 2017).

Code	Name	Definition	Functional Relationship[7]
Agr-1	Percentage of utilised agricultural land	Percentage ratio between utilised agricultural land and total agricultural land	+
Agr-2	Agricultural family labour force	Number of farmhouses with family labour force	+
Agr-3	Impact of employment in the agricultural sector	Percentage ratio between those employed in agriculture and the total number of employees	+
Agr-4	Crop diversification	Degree of subdivision of land into different crops	-
Agr-5	Percentage of surface in protected areas	Percentage ratio between municipal protected areas and total municipal area	+
Pop-1	Percentage of rural population	Number of population belonging to "rural cells" of grid defined by EUROSTAT	+
Pop-2	Demographic sensitivity index	Index function of population density, area of inhabited and productive localities and old-age index	+

Tab.3 Context Analysis: sensitivity indices

Agricultural Sector indices describe the current situation both of lands and agricultural employment, while Population indices assess the human sensitivity to climate-hazard exposure.

Almost all of proposed indices are directly available at municipal scale, normally through data provided by national statistics.

A short explanation is needed about the index Agr-4. Currently, crop diversification is universally recognized as a best practice to increase soil quality and productivity of a land (Lin, 2011; Mustafa et al., 2019; Piedra-Bonilla et al, 2020). For determination of index Agr-4 authors follow criteria established by a Special Report of Court of Auditors of 2017 "*Greening: a more complex income support scheme, not yet environmentally effective*"[8]. The report explains that crop diversification is guaranteed when: if arable land exceeding 30 hectares, it should host at least three crops (1st criterion); the share of arable land devoted to main crop is limited to 75% (2nd criterion); the two main crops taken together must not cover more than 95% of arable land (3rd criterion).

According to these disposition, Agr-4 is calculated as follow:

- if municipal utilized agricultural land doesn't respect 1st or 2nd criterion, Agr-4 is equal to 0;
- if municipal utilized agricultural land respects 1st and 2nd criterion, Agr-4 is calculated as in Formula (7).

$$Agr - 4 = 100\% - (\%MC_1 + \%MC_2) \tag{7}$$

Where $\%MC_1$ and $\%MC_2$ are respectively the percentage of first and second main crops.

Adaptive capacity is similar to or closely related to a host of other commonly used concepts, including adaptability, coping ability, management capacity, stability, robustness, flexibility and resilience (Adger & Kelly, 1999; Jones, 2001; Füssel & Klein, 2006; Smit & Wandel, 2006). At the local level the ability to undertake adaptations can be influenced by such factors as social situation, level of literacy or employment, economic well-being, technological and information resource, infrastructure, the institutional environment and the political influence (Adger et al., 2001; Wisner et al., 2004). Indices chosen by authors (SocEco-1, SocEco-2, SocEco-3, SocEco-4, SocEco-5) are illustrated in Tab.4.

Also for the assessment of Adaptive Capacity, almost all indices are available at municipal scale into several national databases. All of them can be evaluated numerically, except for SocEco-4 that needs for a qualitative

[7] It expresses the contribution of the single indicator to increase (+) or decrease (-) sensitivity dimension.

[8] Available at https://www.eca.europa.eu/Lists/ECADocuments/SR17_21/SR_GREENING_EN.pdf. [Accessed on 4 December 2020].

estimation based on the assessment of the presence of a municipal Emergency Plan and its level of updating, following criteria described below:

- Absence of an Emergency Plan, SocEco-4 = 0;
- Presence of a not-updated Emergency Plan, SocEco-4 = 0.33;
- Presence of an updated Emergency Plan (not digital), SocEco-4 = 0.66;
- Presence of an updated Emergency Plan (digital), SocEco-4 = 1.

Index Code	Name	Definition	Functional Relationship[9]
SocEco-1	Level of economic well-being	Income per capita	+
SocEco-2	Index of social unrest	Index function of 7 factors of social unrest[10]	-
SocEco-3	Level of educational opportunity	Number of schools	+
SocEco-4	Level of preparedness and response capacity	Presence of an updated Municipal Emergency Plan	+
SocEco-5	Level of quality of food and wine productions	Number of certified food and wine products	+

Tab.4 Context analysis: Adaptive capacity indices

4. Case study and results

The proposed methodology was tested on 11 municipalities (01-Bagaladi, 02-Bova, 03-Bruzzano Zeffirio, 04-Cardeto, 05-Ferruzzano, 06-Montebello Jonico, 07-Palizzi, 08-Roccaforte del Greco, 09-Roghudi, 10-San Lorenzo, 11-Staiti) belonged to Grecanica Area, a territorial context located in southern Calabria, Italy. Grecanica Area is considered of particular national interest not only because it is a rural area (according by EUROSTAT (2011) classification) strongly suited to agriculture sector, but above all because it is one of 72 Pilot Areas by Italian National Strategy of Inner Area[11] and was interested in European LEADER program 2014-2020. On a total area of 434.80 km^2, San Lorenzo is the municipality with the largest extension (64.50 km^2), while the smallest one is Staiti (16.30 km^2). Fig. 2 shows the main characteristics of the study area, in terms of morphological conditions, location of areas exposed at hydrogeological risks and the evolution of demographic situation in the last 30 years.

This last aspect deserves a little specification because it is at the same time the cause and the effect of many socio-economic dynamics. The depopulation of the inner towns and villages began in the 60s of the last century with emigration to the Northern Italy and abroad or to the coast and the city of Reggio Calabria. Following classification offered by Lanzani e Zanfi (2019), authors proposes the demographic trend map of Fig. 2 dividing study area in three classes, associating the first letter of alphabetical string of the map legend to the period 1991-2001, the second to 2001-2011, the third to 2011-2019, according to the following code: D= demographic decrease, S=demographic stability, G=demographic growth. Almost all municipalities of study area present a persistent decrease of population, except for Palizzi and Ferruzzano that today have a

9 It expresses the contribution of the single indicator to increase (+) or decrease (-) adaptive capacity dimension.

10 Considered factors are: percentage of population aged between 25 and 64 who are illiterate and literate without a qualification; percentage of households with 6 and more members; percentage of young single-parent families on the total of families; percentage of families of only elderly people (65 years and over) with at least a member over eighty; percentage of population in conditions of severe crowding; percentage of NEET (young people (15-29 years) Not in Education, Employment or Training); percentage of families with children in which no one is employed.

11 SNAI, 2014, Strategia Nazionale per le Aree Interne: definizione, obiettivi, strumenti e governance. Available at: https://www.miur.gov.it/documents/20182/890263/strategia_nazionale_aree_interne.pdf/d10fc111-65c0-4acd-b253-63efae626b19 [Accessed on 11 December 2020].

demographic stability after a long period of decrease and Montebello Jonico with a slight reversal of a negative demographic trend.

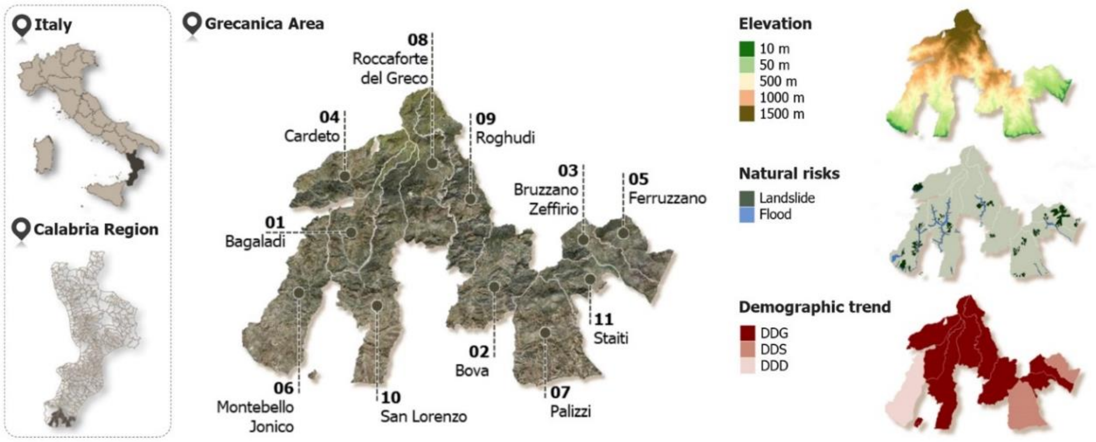

Fig.2 Study area

The effect of depopulation emerges from the high number of unoccupied housing stock (ISTAT, 2011) – that represents a serious danger in case of earthquake (Calabria is the one of the Italian regions with the highest seismic risk) – but also from the state of neglect of many lands, once utilized and that represented a great resource both for agricultural sector and the whole local economy, strongly affected by climate change too.

4.1 Grecanica Area: climatic analysis

In order to define the indices in accordance with the proposed methodology, we have identified the stations equipped with thermometer and rain gauge located in the study area and in the buffer zone. We evaluated each series recorded by the stations through the parameters of continuity, completeness and quality and excluded the stations that did not meet the above requirements. Once the stations have been identified, we have built the Voronoi polygons (Fig.3).

For each municipality the influencing stations were calculated on the basis of the Voronoi polygons and each station was associated with a weight equal to the ratio between the area of the polygon falling within the municipality and the total area of the municipality (Tab.5).

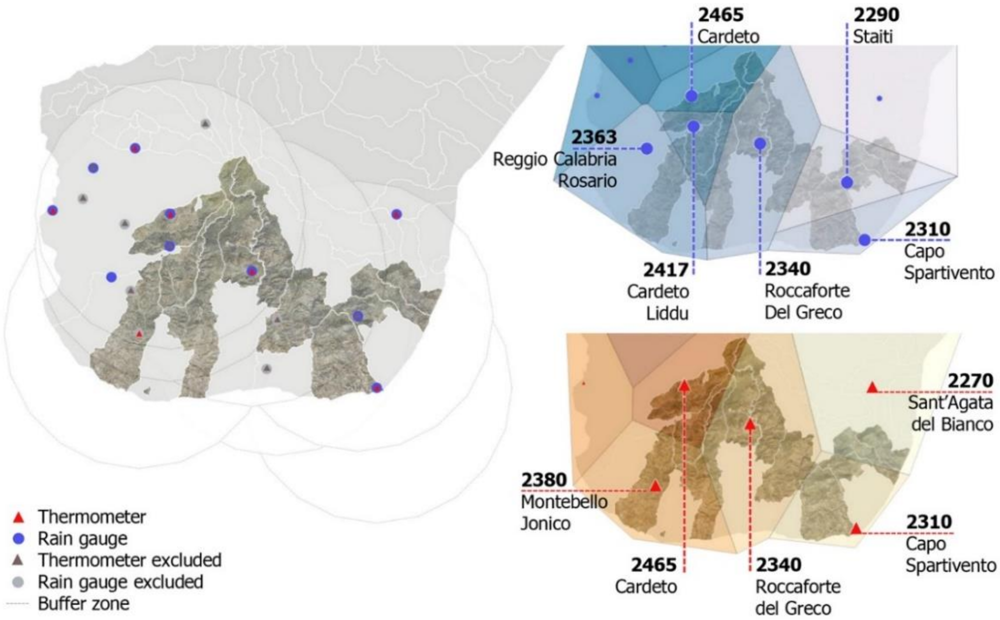

Fig.3 Climatic analysis

4.2. Grecanica Area: context analysis

In accordance with the proposed methodology, context analysis regards the assessment of sensitivity and adaptive capacity dimensions, respectively characterized by indices on agricultural sector and socio-economic features.

Particularly, the main source of data used by authors is Italian National Statistics Institute that provides information both for agriculture (ISTAT, 2010), population (ISTAT, 2011) and socio-economic conditions. Data on protected area are available on national Ministry of the Environment and the Protection of the Sea database (2020), while information about rural population are extracted from data of EUROSTAT grid (2011).

Especially for adaptive capacity analysis, in addition to already mentioned ISTAT data source, authors consulted Open Data of Italian Ministry of Economy and Finance (2019) for calculating municipal income per capita, while they carried out a municipality-by-municipality assessment for evaluating the presence of a municipal Emergency Plan.

Municipality		Thermometer			Rain Gauge		
ID	**Area (km^2)**	**ID**	**Area (km^2)**	**Weight**	**ID**	**Area (km^2)**	**Weight**
01	29.83	2465	19.46	0.65	2465	3.45	0.12
		2380	9.32	0.31	2417	25.90	0.87
		2340	1.05	0.04	2363	0.48	0.02
02	46.51	2340	45.25	0.97	2340	24.46	0.53
		2310	1.26	0.03	2290	22.05	0.47
03	20.52	2270	14.32	0.70	2270	0.01	0.00
		2310	6.20	0.30	2290	20.51	1.00
04	37.24	2465	37.24	1	2465	20.75	0.56
					2417	15.91	0.43
					2363	0.57	0.02
05	18.92	2270	17.95	0.95	2270	3.93	0.21
		2310	0.97	0.05	2290	14.99	0.79
06	55.98	2380	53.76	0.96	2417	4.25	0.08
		2465	2.22	0.04	2363	51.73	0.92
07	52.36	2310	52.15	1.00	2290	24.75	0.47
		2340	0.21	0.00	2310	27.60	0.53
08	43.47	2340	37.30	0.86	2340	35.94	0.83
		2465	6.17	0.14	2465	7.53	0.17
09	44.88	2340	41.78	0.93	2340	36.53	0.81
		2465	2.55	0.06	2465	7.81	0.17
		2380	0.55	0.01	2363	0.55	0.01
10	63.89	2465	4.39	0.07	2465	2.86	0.04
		2340	25.23	0.39	2340	39.81	0.62
		2380	34.26	0.54	2417	16.97	0.27
					2363	4.26	0.07
11	16.16	2310	15.59	0.97	2290	1.62	1.00
		2270	0.56	0.03			

Tab.5 Grecanica Area: station weigth

In Italy, Civil Protection is the responsible Body for emergency management and every municipality is forced to have an Emergency Plan according to dispositions of Italian Legislative Decree 1/2018. Still today, however, not everywhere there is a plan or, where present, it is not properly update.

A research carried out by Laboratory of Environmental and Territorial Planning (LabPAT) of the Department of Civil Engineering (DINCI) of the University of Calabria, has highlighted the critical situation of emergency planning in Calabria Region at early 2017 (Francini et al., 2018).

		Index	01	02	03	04	05	06	07	08	09	10	11
EXPOSURE	Clim-1	FD0 (days)	29.0	11.5	0.9	43.0	1.2	3.2	0.3	16.2	13.4	8.5	0.3
		TR20 (days)	20.0	38.2	78.8	2.5	69.9	52.6	103.4	31.6	34.7	43.9	102.4
		TNx (°C)	23.1	26.9	27.9	20.9	27.7	27.0	28.5	26.1	26.6	26.7	28.5
		TNn (°C)	-5.5	-3.9	-0.1	-7.3	-0.6	-2.0	1.5	-4.5	-4.2	-3.1	1.4
		TN10p (%)	9.7	9.6	9.7	9.7	9.6	9.8	9.7	9.6	9.6	9.7	9.7
		TN90p (%)	9.6	9.8	10.2	9.6	10.1	9.7	10.2	9.8	9.8	9.7	10.2
	Clim-2	SU25 (days)	49.9	69.0	113.7	33.1	113.1	81.2	115.0	62.8	65.9	73.6	115.1
		TXx (°C)	32.5	34.4	37.0	31.1	37.4	35.0	35.7	33.9	34.2	34.6	35.8
		TXn (°C)	-1.2	0.4	5.0	-3.1	4.2	2.3	7.2	-0.3	0.1	1.3	7.1
		TX10p (%)	9.6	9.7	9.6	9.5	9.7	9.7	9.5	9.7	9.7	9.7	9.5
		TX90p (%)	9.6	9.8	10.2	9.6	10.1	9.7	10.2	9.7	9.8	9.7	10.2
		WSDI (days)	9.6	9.8	10.2	9.6	10.1	9.7	10.2	9.7	9.8	9.7	10.2
	Clim-3	RX1day (mm)	67.2	103.8	92.2	91.9	103.2	121.1	75.8	114.6	114.7	100.7	92.1
		RX5day (mm)	99.7	186.9	167.1	143.2	180.8	178.0	132.5	201.3	201.1	171.2	167.1
		R10 (days)	21.2	28.7	28.6	29.9	28.8	38.7	22.7	30.5	30.7	27.3	28.6
		R20 (days)	8.6	13.1	13.9	13.8	14.3	18.8	10.6	13.4	13.5	11.7	13.9
		R95P (mm)	443.8	675.7	643.6	596.4	669.0	740.4	516.6	711.5	712.3	629.2	643.5
		SDII (mm/day)	9.0	12.6	13.5	10.7	13.6	12.9	11.5	11.9	11.9	11.1	13.5
		Clim-4 (%)	50.29	27.07	16.55	2.54	18.14	47.17	62.91	0.00	4.89	32.32	32.29

Tab.6 Grecanica Area: indices' values of climatic analysis

Municipality	Francini et al., 2018	National Civil Protection, 2020	Elaboration year (in-depth analysis)	Final data
01	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2017	Presence of an updated Emergency Plan (not digital)
02	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2012	Presence of a not-updated Emergency Plan
03	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
04	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
05	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
06	Absence of an Emergency Plan	Presence of an updated Emergency Plan	2017	Presence of an updated Emergency Plan (not digital)
07	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2014	Presence of a not-updated Emergency Plan
08	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	2012	Presence of a not-updated Emergency Plan
09	Absence of an Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
10	Absence of an Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan
11	Presence of a not-updated Emergency Plan	Presence of an updated Emergency Plan	Absence of an Emergency Plan	Absence of an Emergency Plan

Tab.7 Grecanica Area: SocEco-4 index assessment

The results show that 35% of Calabrian municipalities didn't have an Emergency Plan and in almost 50% of cases, although the plan was present, it was elaborated at least 20 years before.

Today the situation seems to be better and, although digital plans available for online consultation on WebGIS platform are very few, national Civil Protection states that 96% of Calabrian municipalities has an emergency plan[12], even if, particularly from Grecanica Area, in-depth researches describe a framework a little bit difference.By processing the historical series (1999-2019) and considering the weights associated with each station, the indices shown in Tab.6 were evaluated for each municipality.

For the specific aim of this study a not-available plan can't be considered as an element of adaptive capacity: for sure, in this case, people cannot be informed properly before and during a crisis.

According to these assumptions, information collected for case study municipalities are reported in Tab. 7. Tab. 8 Shows results of data collection for context analysis, with specific focus on sensitivity and adaptive capacity assessments.

	Index	01	02	03	04	05	06	07	08	09	10	11
SENSITIVITY	Agr-1 (%)	43.39	38.81	45.54	12.41	35.77	35.34	36.11	21.04	32.42	41.80	18.62
	Agr-2 (N)	278	198	126	122	144	821	166	75	91	717	39
	Agr-3 (%)	47.50	17.90	11.60	32.70	0.70	14.60	15.00	56.20	41.80	29.40	18.40
	Agr-4 (%)	6.00	5.00	8.00	22.00	29.00	12.00	14.00	0.00	0.00	12.00	5.00
	Agr-5 (%)	51.00	59.00	1.00	13.00	0.00	0.00	1.00	100.00	95.00	30.00	24.00
	Pop-1 (%)	14.97	32.10	31.71	69.54	20.54	21.02	8.53	40.55	9.13	12.89	47.67
	Pop-2 (-)	4.94	8.25	5.22	4.79	5.38	0.56	4.44	9.89	5.11	3.59	10.05
ADAPTIVE CAPACITY	SocEco-1 (€)	12768	13190	11642	11785	14659	13038	14069	14155	11769	13259	11886
	SocEco-2 (-)	102.31	99.48	101.04	102.84	99.34	103.83	102.80	101.30	108.28	104.61	102.47
	SocEco-3 (N)	3	2	4	6	3	13	4	3	3	10	0
	SocEco-4 (-)	0.66	0.33	0.00	0.00	0.00	0.66	0.33	0.33	0.00	0.00	0.00
	SocEco-5 (N)	0	2	0	2	1	0	1	0	0	0	1

Tab.8 Grecanica Area: indices' values of context analysis

4.3 Grecanica Area: vulnerability assessment

Results showed in Fig.4 are obtained for each dimension of exposure, sensitivity and adaptive capacity after normalization and aggregation operations.

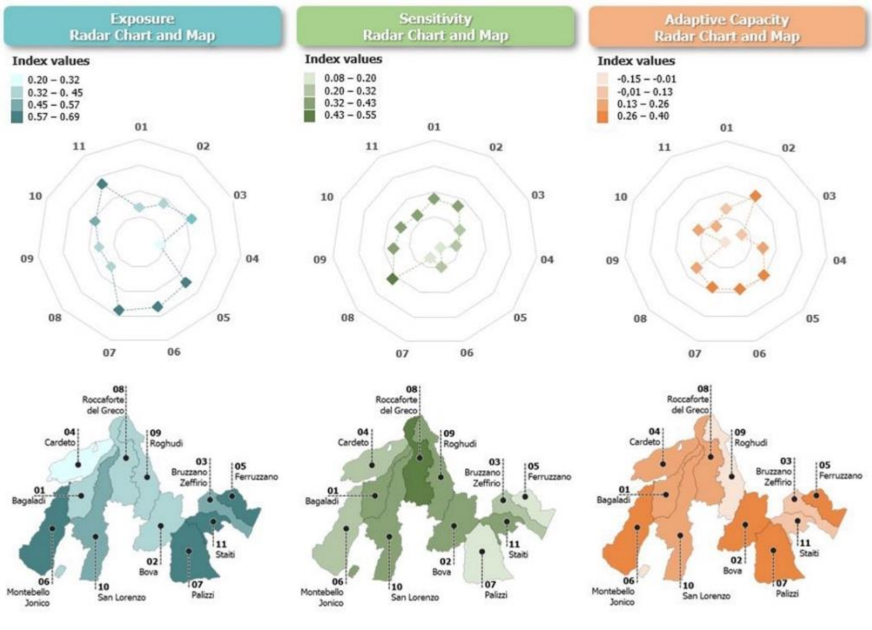

Fig.4 Index radar charts and maps of exposure, sensitivity and adaptive capacity assessments

[12] Information available at http://www.protezionecivile.gov.it/servizio-nazionale/attivita/prevenzione/piano-emergenza/mappa-piani-comunali/calabria

Vulnerability Index is calculated by combination of previous three dimension as established by Formula (3). Fig.5 presents the results described through a radar chart and a vulnerability map[13].

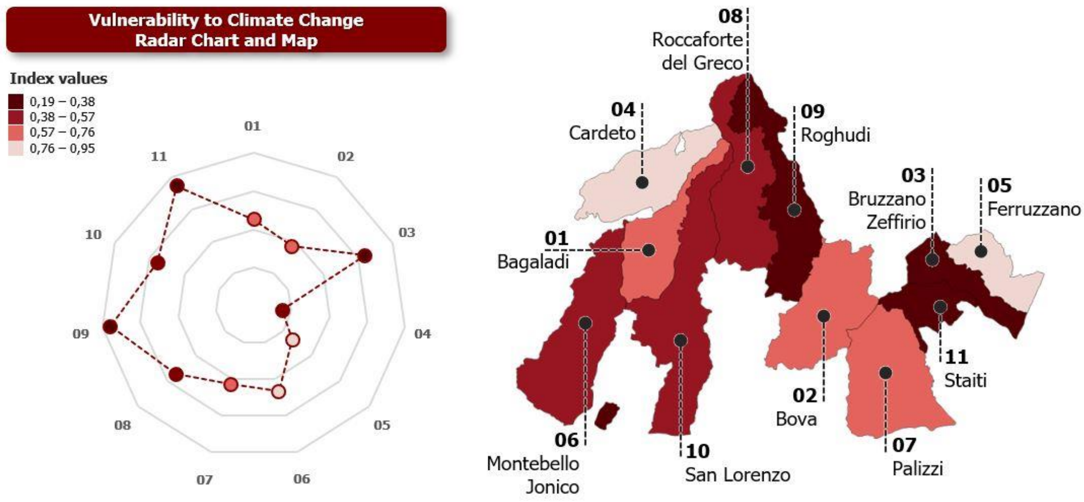

Fig.5 Grecanica Area: vulnerability index radar chart and vulnerability map

5. Discussion and conclusions

This paper proposes the application of a methodology to measure municipal vulnerability to climate change focusing on agricultural sector, through a Vulnerability Index (VI) that synthetize climatic and contextual factors (environmental and socio-economic) with respect to three components that are climatic exposure, sensitivity and adaptive capacity. The study area is composed by 11 municipalities with rural vocation located in province of Reggio Calabria (Southern Italy). Climatic analysis on the study areas have concerned extreme of cold, extreme of heat, extremes of precipitation and the desertification risk. The results show a significant level of exposure in all the municipalities observed with normalized values of the Exposure Index (EI) ranging between 0.20 and 0.69 (average value of 0.49 and standard deviation of 0.16). Municipalities that fall in areas most exposed to climate change ($EI > 0.5$) are nearly on 50% of all municipalities in the considered area. In particular, Palizzi has the highest exposure index (0.69), followed by Staiti (0.66) and Montebello Jonico (0.66). Cardeto has the lowest exposure index (0.20), followed by Bagaladi (0.33) and Roccaforte del Greco (0.37).

The context analysis has shown a significant dependence of the local economic system on agriculture (specifically, the indices Agr-1, Agr-2, and Agr-3 demonstrate this), which, combined with the significant level of exposure to climate change, demonstrates the importance of deepening studies on the level of local vulnerability. The context analysis led to the definition of the sensitivity index and the adaptive capacity index. Sensitivity Index (SI) ranging between 0.08 and 0.55 (average value of 0.31 and standard deviation of 0.14). Roccaforte del Greco has the highest sensitivity index (0.55), followed by Bagaladi (0.42) and Bova (0.42). In particular, in these three cases, Pop-2, Agr-5 and Agr-3 indices are particularly influential in the calculation of the index. Palizzi has the lowest sensitivity index (0.15), followed by Cardeto (0.21) and Montebello Jonico (0.25). Adaptive Capacity Index (ACI) ranging between -0.15 and 0.40 (average value of 0.19 and standard deviation of 0.16). Bova has the highest adaptive capacity index (0.40), followed by Ferruzzano (0.35) and Montebello Jonico (0.32). Roghudi has the lowest adaptive capacity index (-0.15), followed by Bruzzano Zeffirio (0.02) and Staiti (0.05). Overall, the Vulnerability Index was obtained as a function of the three aforementioned indices using formula (3). The Vulnerability Index (VI) ranging between 0.19 and 0.95 (average value of 0.61 and standard deviation of 0.23). The three most vulnerable municipalities are Roghudi ($VI = 0.95$), Staiti ($VI = 0.93$), and Bruzzano Zeffirio ($VI = 0.93$) and coincide with those with a lower level of adaptive capacity. The

[13] Vulnerability Index thresholds are obtained through the application of QGIS algorithm "equal interval".

results highlight the importance of taking measures to improve the adaptive capacity through the municipal planning.Starting from obtained results, authors compared them with indications of already cited SNAI Pilot Area and European LEADER Program elaborated for the same study area. Pilot Area Strategy[14] recognizes agricultural sector as a big development opportunity for local economy, providing specific actions detailed on E Intervention Sheet. However, no action aims at mitigating neither climate change effects nor other type of risks: moreover, no reference is done to current risk conditions neither in Annex A of territorial analysis to reflect the fact that seems to be no risk perception. Similarly, European LEADER Program, while identifying rural vocation of Grecanica Area and underling the state of abandonment of the lands and the lack of maintenance of agricultural activity, doesn't provide effective indications for possible mitigation measures and doesn't treat climate change at any point. Adaptive capacity goals are never mentioned in neither strategy.
Definitely, considering that Civil Protection Municipal Plan is currently the only tool treating the risk theme and that, however, it presents significant critical issues as specified in section 4.2., authors believe that two paths are possible: a review of Emergency Plan for inserting new vulnerability considerations as well as climate change ones in order to follow a new global preventive planning perspective; the introduction of a local Climate Change Adaptation Plan able to consider better specific characteristics of the area in a mitigation site-specific view. In particular, with reference to the first option, the integration with the new global preventive planning perspective could concern coordination with European policies such as SECAP for a vulnerability assessment that allows to define more detailed risk scenarios and consequent adaptation and mitigation actions in different policy sectors (Bertoldi, 2018) and for the different types of risk. In this sense, the role of the Civil Protection could concern the planning phase for the identification, evaluation and decisions on the discipline of land use, but also the phase of implementation of actions to combat climate change and the subsequent monitoring phase, as partly predicted by Neves, et al. (2016).
Enriching a sector plan of different contents and new objectives or introducing a new tool, however, wouldn't be enough: in order to make strategies more effective – especially at area level – ordinary planning process should be responsible of a better coordination among DDR and CCA approaches in "time of peace" and not only in emergency conditions.

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Emergency and spatial planning towards cooperative approaches

Challenges and opportunities in the multi-risk area of Campi Flegrei

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Abstract
The dependency of risk scenarios on the dynamics of urban transformation clearly highlights the need of ensuring a closer cooperation between spatial and emergency planning processes. So far the relationships between the two processes have been rather limited, leading at most to the transposition of the emergency plans' indications in the spatial plans. Nevertheless, more cooperative approaches would be crucial to increase safety, resilience and sustainability of human settlements, above all when they are threatened by different hazard factors. In order to explore barriers and opportunities for a better cooperation between emergency and spatial planning processes, this contribution will focus on the Campi Flegrei in the Campania Region (Southern Italy): a densely populated area, hosting a significant historical, cultural, and natural heritage, and prone to volcanic, seismic and hydrogeological hazards. The case study area is also characterized by the coexistence of emergency and spatial planning tools acting on different geographical scales, developed by different actors and not always fully consistent each other. In detail, based on the analysis of the location and accessibility of emergency facilities, crucial to guarantee an effective response in the aftermath of hazardous events, we will here highlight both the main criticalities of the emergency plans recently carried out for the selected Municipalities and the difficulties and opportunities related to a better integration between spatial and emergency planning at municipal scale.

Keywords
Emergency planning; Spatial planning; Multi-risk areas.

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1. Emergency and spatial planning: what opportunities for a more effective cooperation?

The importance of carrying out in peacetime emergency plans capable of increasing the capacity to cope with the numerous critical issues arising in the aftermath of hazardous events – from the evacuation procedures to the first aid to the hit populations – has been stressed by numerous scholars over the last two decades (Perry and Lindell, 2003; Lindell and Perry, 2007; Alexander, 2015). The definition in advance of expected risk scenarios, involved stakeholders, intervention procedures as well required and available resources are now commonly interpreted as prerequisites for ensuring the timeliness and effectiveness of the emergency response (Lindell, 2013).

However, the effectiveness of the emergency management largely depends on the overall features of the complex process, which has in the emergency plan its main outcome, aimed at increasing the response capacity of communities and local institutions in the aftermath of the event (Menoni, 2013).

Among the key requirements of an effective emergency planning process, the dynamic features of the process itself and the flexibility of the planned actions must be mentioned. Since the primary goal of an emergency plan is to offer operational responses to the different risk scenarios that may occur in a given area, first of all the knowledge base, which risk scenarios are based on, has to be constantly updated: risk scenarios are, indeed, far beyond from being a static picture, since they constantly evolve due to the change both of the hazard features and of the characteristics of the potentially hit areas (Di Lodovico & Di Ludovico, 2018).

Furthermore, the foreseen measures should be flexible and adaptable in order to better cope both with the uncertainty, inevitably linked to the available risks knowledge, both with the likely occurrence of unexpected events or impacts (FEMA, 2010) that often result from complex chains of primary and secondary events and related impacts (Galderisi, 2020).

Besides, an emergency plan represents the outcome of a multi-actor process, based on the active involvement of a wide range of stakeholders: from the multiple actors in charge of different sectors of emergency management (decision makers at local, regional and national levels; managers of critical infrastructures, etc.) to the communities potentially affected by the different emergency measures. Thus, a further requirement of an effective emergency planning process is the capacity of identifying in advance the involved stakeholders, their specific responsibilities and tasks, the intervention procedures and cooperation mechanisms, the features of the communities potentially affected by a given hazard, such as the factors that might affect their response in emergency phase (age, disability, language barriers, etc.), and the potential needs arising from the different components of a community in the aftermath of the event. A direct engagement of local communities in the emergency planning process should allow not only to increase the sense of responsibility of community members, but also to build up a more in-depth knowledge of their heterogeneous background, experiences and expectations, revealing in many cases fragilities that are difficult to infer from the traditional statistical analyses of social fabric (FEMA, 2011).

According to the main features of an effective emergency planning process previously outlined, it seems appropriate to question whether and how this could benefit from a greater cooperation with spatial planning processes. To date, unfortunately, the relationships between emergency or civil protection plans – as currently defined by the 2018 Civil Protection Code – and spatial plans are generally limited to the transposition into the latter of the emergency areas established by the former (waiting areas, reception areas, storage areas) and to the use of data and information provided by spatial plans (when available) in order to identify the assets exposed to different hazards in the civil protection plans. However, some of the disasters that affected Italy in the last decade brought out the numerous criticalities arising from the fragmentation of competencies and plans in the field of risk management and spatial planning, pushing towards a more effective cooperation. A relevant example in this line is the multilevel collaboration among municipalities, provincial and regional authorities carried out in the Region Emilia Romagna. Following the 2012 earthquake, the Province of Modena took a leading role, ensuring an operational support to all the affected municipalities, guiding them in identifying the network of the strategic elements at the provincial scale and, in some cases, in integrating the results of the analyses carried out in the municipal spatial plans (Manicardi et al. 2014).

Hence, renewed approaches both to emergency planning – aimed at improving its consistency with the main requirements currently provided by scholars and institutional guidelines – and to spatial urban planning – aimed at ensuring a more effective integration of risk reduction issues in planning tools – could lead to new relationships, cooperative and synergistic, among these tools, facilitating meanwhile the development of integrated policies, capable of increasing sustainability and safety of human settlements to the various risk factors they are exposed to (Francini et al. 2018b).

The need of considering risk not as a 'sector' but as a crucial issue of the regular development policies and of promoting an integrated governance to better dealing with disasters are not new issues, since they have been stressed by scholars since the early 2000s (Christoplos et al., 2001; Djalante, 2012). Furthermore, the 2030 Agenda for Sustainable Development, and namely the goal 11 "Make cities and human settlements inclusive, safe, resilient and sustainable", clearly emphasizes the need of "adopting and implementing integrated policies and plans" to improve settlements' resilience to disasters, as well as of developing and implementing "in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels".

Moreover, it is worth noting that both the considered planning processes are confronted with "spatial" issues (Alexander, 2015), related to the singling out of intervention areas as well to the location in safe and equally accessible areas of facilities serving the community in peace or in crisis times.

Currently, most of the regional guidelines for emergency planning in Italy direct to the consultation of spatial plans for a precise identification of the exposed assets, while very few refer to the need for Geographical Information Systems (GIS) capable of collecting, processing and integrating data and information from heterogeneous sources able to support all the decision-making processes aimed at reducing risks, managing emergencies and improving citizens' awareness on the risk features of the territories they live in (Regione Puglia, 2019). Hence, the building up of shared and integrated GIS, capable of supporting both territorial and emergency planning could represent a relevant step towards a better cooperation. The risk scenarios outlined by the civil protection plans, based on detailed analyses at local scale of the different natural or man-made hazards, could represent an important information, far more detailed than those generally used and derived from the first level sectoral plans, for risk-informed urban planning processes. On the opposite, the detailed analysis of the heterogeneous features of the local context set up by the spatial plans could provide a more in-depth knowledge of the multiple dimensions of vulnerability – connected to spatial, functional, social, economic dynamics – crucial to a more effective emergency management. The post-event crisis often reveals, in fact, unexpected functional, social and systemic vulnerabilities that, if not adequately and timely addressed, may significantly increase secondary or indirect damage.

A further area of potential cooperation between the two planning processes relates to the choice of the most adequate areas and routes to be allocated to the civil protection needs. Currently, emergency areas and routes identified by civil protection plans are incorporated in spatial plans, which assign them compatible land uses, aimed at ensuring their adequate maintenance in peacetime. However, these areas and routes, which have to be identified and located according to specific requirements (morphological and dimensional characteristics, accessibility criteria, safety, underground services, etc.), could represent key elements of wider networks of public urban spaces – open spaces, green areas, urban facilities – and sustainable mobility paths. These networks, adequately designed and equipped also in terms of furnishings and signs, could be crucial both to increase quality and livability of settlements in peacetime and to improve their response in crisis times. Yet, such a possibility would require a shift from the traditional focus of civil protection plans on individual elements, functional to the emergency management, towards a multi-objective perspective addressed to redesign the

whole urban system to better cope with the heterogeneous demands that a community poses, in peace and in crisis times.
Finally, the hoped-for transition of emergency planning processes, also required by the 2018 Civil Protection Code, from top-down processes to more inclusive and participatory processes, capable of ensuring a greater integration between expert and local knowledge as well as of envisioning solutions shared with local communities, could open up new opportunities for cooperation. The engagement of local communities in decision-making processes has represented, in fact, a priority for spatial planning since the late 1990s: in this field numerous methods and formats have been developed, which could be usefully translated and applied into emergency planning processes, so far largely interpreted as technical processes, mostly entrusted to experts.
Summing up, the enhancement of cooperative relationships between spatial and emergency planning processes could contribute to increasing the quality and effectiveness of both, laying the foundations for building up safer cities, in which development/regeneration choices might actively contribute both to risk reduction and to the design of networks of public spaces that, based on criteria of flexibility and redundancy, could answer multiple needs, including that one of ensuring a more effective and immediate response of urban systems in case of hazardous events.

2. Spatial and emergency planning in a multi-risk environment: the case study of Campi Flegrei

In respect to the previously discussed features of emergency plans and to the desirable synergies between emergency and spatial planning processes, we will focus here on the interactions between these processes in the Phlegraean Fields (Campi Flegrei) (Fig. 1): one of the most critical areas within the metropolitan area of Naples, due to its multi-hazard features combined with a high population density and a rich historical, archaeological and natural heritage. The area is a vast volcanic caldera (with a diameter of about 10 km), partly emerged and partly submerged, whose volcanic activity has been characterized by series of explosive eruptions occurred from vents scattered inside the caldera (Macedonio et al., 2012). The peculiarity of the Phlegraean Fields, compared to the volcanic areas characterized by a central volcanic system as the Vesuvius, is that in this case the area of possible opening of eruptive vents is very large, with significant consequences in terms of extension of the potentially affected territory.
The Decree of the President of the Council of Ministers, issued in 2016 and titled "Provisions for updating the emergency planning for volcanic risk of Phlegraean Fields", divided this area into two zones:

- a red zone, exposed to pyroclastic flows and including the whole municipalities of Monte di Procida, Bacoli, Pozzuoli and Quarto and part of the municipalities of Naples, Marano and Giugliano in Campania; this area currently hosts about 500,000 inhabitants;
- a yellow zone, exposed to pyroclastic fallout, which involves the remaining part of the municipal territory of Naples, except the eastern area of Ponticelli, and numerous municipalities located north of Naples (Marano, Mugnano, Calvizzano, Villaricca, Melito, Casavatore).

As mentioned above, the Phlegraean Fields represent a paradigmatic example of multi-risk area: in addition to the volcanic hazard, this area is prone to several hazard factors including earthquakes, floods and landslides. All the Municipalities fully included in the red zone show a maximum ground accelerations value ranging from 1.55 and 1.70[1]: thus, all of them are classified as seismic zone 2. These Municipalities are also characterized by high values of population density and host more than 300 buildings and sites of high architectural or archaeological value.

[1] Acceleration with probability of exceeding 10% in 50 years (ag). Further details on the seismic classification of the Italian territory are available at: http://www.protezionecivile.gov.it/attivita-rischi/rischio-sismico/attivita/classificazione-sismica [Accessed 1/12/2020]

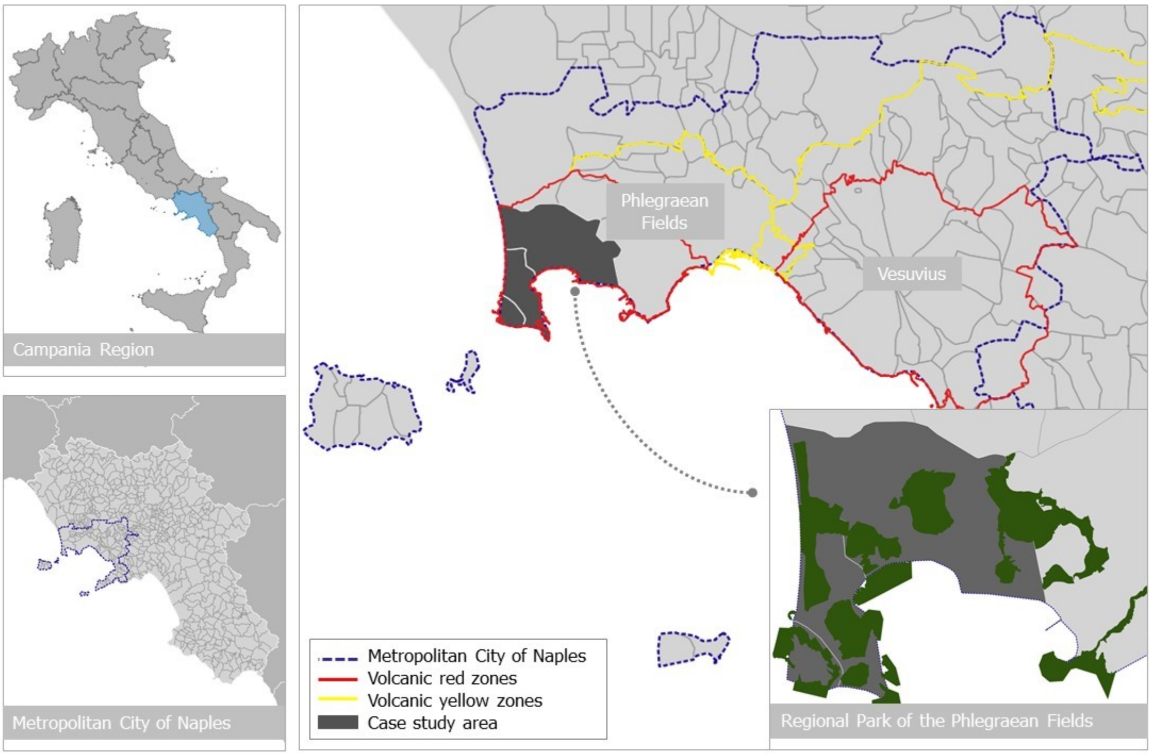


Fig.1 The case study area and its territorial context

Moreover, in the considered area about 65% of residential buildings were built before 1980: it is worth reminding that the first Law (the Law 64) providing a national seismic classification of the Italian territory as well as the first seismic building codes was issued in 1974. Furthermore, more than 6% of the population resides in areas characterized by high and very high landslide hazard levels (P3 and P4), while about 2% in areas characterized by medium or high hydraulic hazard levels (P2 and P3)[2].

The features of the case study area and the numerous hazard factors it is prone to would have required the implementation of measures aimed at reducing its exposure and vulnerability, especially through spatial plans capable of limiting building growth, at least in the areas at higher risk.

Unfortunately, spatial planning in the metropolitan area of Naples has been for long characterized by a significant inertia both on a territorial and on a municipal scale: for example, the Metropolitan Territorial Plan – which is the review of the previous Territorial Coordination Plan drawn up at Provincial scale even before the establishment of the Metropolitan city – is still waiting for a final approval, while in 2020 the Strategic Metropolitan Plan has been approved. This document, despite recognizing the multi-risk features of the metropolitan area, provides an articulation of the area in five homogeneous zones, which does not fully reflect the different risk features of the metropolitan territory, namely for the two large volcan areas of Vesuvius and Phlegraen Fields.

The spatial urban plans in six of the seven municipalities of the red zone are prior to the regional planning law issued in 2004, dating back in some cases even more than twenty years ago.

Only the municipality of Monte di Procida has approved a new spatial plan in 2020, while the municipalities of Bacoli and Quarto have carried out a preliminary plan in 2015 (Tab. 1).

Similarly to other cases, such as the Vesuvius and the Etna (Curci, 2020), also in the Phlegraean Fields, the limited attempts to counteract the building growth have been entrusted to the Landscape Plan of the Phlegraean Fields approved in 1996 and by now largely outdated, to the establishment of numerous protected

2 Data source: https://www.istat.it/it/mappa-rischi [Accessed 24/11/2020]

areas included in the Natura 2000 protected areas network and to the Regional Park of the Phlegraean Fields, established in 2003 and still lacking a specific plan.

Municipalities	Plan in force	Plan in progress
Bacoli	Spatial Plan 1976	Preliminary Plan 2015 (update 2017)
Giugliano	Spatial Plan 1985	-
Marano di Napoli	Spatial Plan 1987	-
Monte di Procida	Spatial Plan 2020	-
Napoli	Spatial Plan 2004	Preliminary Plan 2020
Pozzuoli	Spatial Plan 2002	-
Quarto	Spatial Plan 1994	Preliminary Plan 2015

Tab. 1 Spatial Plans in the municipalities of the red zone: updating status

However, despite the severe constraints provided since the end of the Nineties by landscape-environmental planning, in the time span 2006 and 2018 the extension of residential urban fabrics[3] has increased of about 2,8% in the red zone (Fig. 2).

The limited measures aimed at reducing or at least avoiding a further increase of the already significant exposure of the Phlegraean Fields and the lack of interventions to reduce its vulnerability in the face of the heterogeneous hazards that this area is exposed to, assign a difficult task to emergency planning. The latter is required, in fact, to outline measures able to cope with complex risk scenarios in a context where the high residential density is combined with a limited risk perception (Ricci, Barberi et al., 2013).

Very few actions have been so far put in place in order to improve local risk awareness: in particular, it is worth mentioning the information campaign "I do not risk", promoted by the Civil Protection in 2019, which included events specifically devoted to the volcanic risk in the Phlegraean Fields.

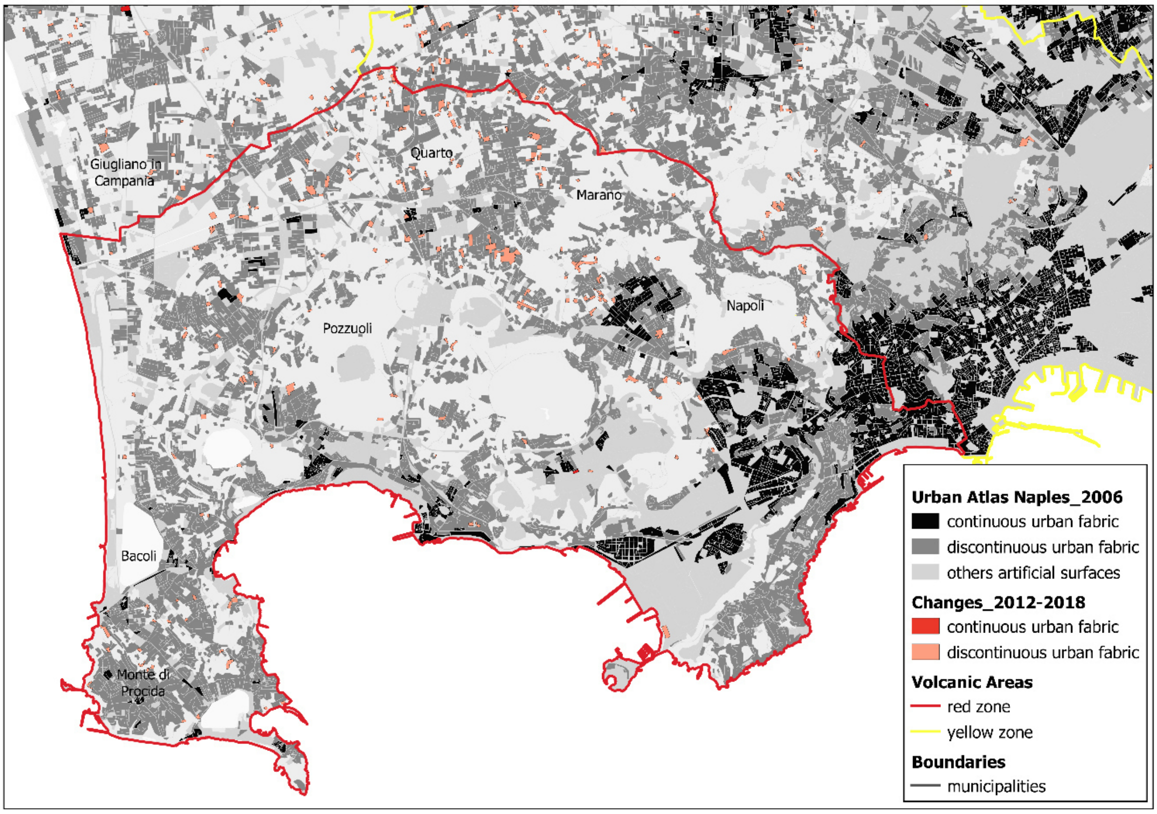


Fig.2 Changes in continuous and discontinuous urban fabric in the Phlegraean Fields between 2006 and 2018

3 Continuous and discontinuous urban fabrics have been distinguished according to the classification provided by Urban Atlas. Further details are available at: https://land.copernicus.eu/local/urban-atlas [Accessed 1/12/2020]

In this complex area, emergency planning has been articulated in two levels:

- the Phlegraean Fields National Plan;
- the Municipal Civil Protection Plans.

The first one, aimed at increasing the response capacity in the face of the likely volcanic risk scenarios, is the result of a long process, started in 2001, which led to: the subdivision of the Phlegraean Fields into two areas – the red and the yellow one – in relation to the expected eruptive scenarios; the definition of the alert levels; the development of the Evacuation Plan for all the Municipalities included in the red zone, where the preventive evacuation is identified as the only measure to ensure the safety of the population. Moreover, the "Provisions for updating the emergency planning for the volcanic risk of the Phlegraean Fields", issued in 2016, identified the twinning scheme between the municipalities of the red zone and selected Italian regions. Finally, the Resolution of the Campania Region 547, issued in September 2018, definitely approved the Evacuation Plan. The latter, carried out by the Campania Region with the support of the Campana Mobility Infrastructure and Networks Agency (ACaMIR) and in collaboration with the concerned Municipalities, outlines the procedures aimed at ensuring an assisted evacuation, in 72 hours, of the entire population that, through a limited number of "gates" identified by the Plan, should be firstly transferred from the "waiting areas", identified by the Civil Protection Plan of each Municipality, to the "meeting areas", located outside the red zone, and then to the "first points reception" located in the twin regions (Fig. 3). In the yellow zone, essentially affected by pyroclastic fallout as well by ash accumulation phenomena, the definition of specific emergency measures is entrusted to the municipal civil protection plans: these measures should be flexible, due to the difficulty of precisely delimiting the area that will be actually affected by pyroclastic fallout, which strongly depend on winds' directions and on the severity of the eruption. As far as municipal civil protection plans are concerned, to date all the municipalities in the red zone, also thanks to the funds put in place by the Campania Region starting from 2014, have adopted a plan or have started, at least, the updating process (Tab.2). Among these plans, three out seven were drafted before the Guidelines for the preparation of the Municipal Emergency Plans[4] issued by the Campania Region (DGR 146 -27.05.2013). Moreover, five of them have been updated after the "Provisions for updating the emergency planning for the volcanic risk of the Phlegraean Fields" issued in 2016, in order to consider the most recent emergency areas defined by the National Plan. In brief, the emergency planning process undertaken for the Phlegraean Fields undoubtedly shows some elements of interest. Among them, the nature itself of the planning process: a multi-scale and multi-actor process that has been developed thanks to a close collaboration between different institutional levels (from national civil protection to individual municipalities). However, it also shows some significant weaknesses.

Municipalities	**Approval date**	**Funding 2014**	**Funding 2017**
Bacoli	2016 (volcanic update 2018)	YES	-
Giugliano	2017 (*being updated*)	YES	YES
Marano di Napoli	2013 (volcanic update 2018)	YES	-
Monte di Procida	2017 (volcanic update 2019)	YES	-
Napoli	2012 (seismic update 2019)	YES	YES
Pozzuoli	2016 (volcanic update 2020)	YES	YES
Quarto	2012 (volcanic update 2018)	YES	YES

Tab.2 Civil Protection Plans in the red zone's municipalities: updating status

4 It is worth noting that the Regional Guidelines, in accordance with Law 100/2012, referred to the Municipal Emergency Plans. It is only with the Civil Protection Code D. Lgs. 1/2018 that these tools have been defined as Municipal Civil Protection Plans.

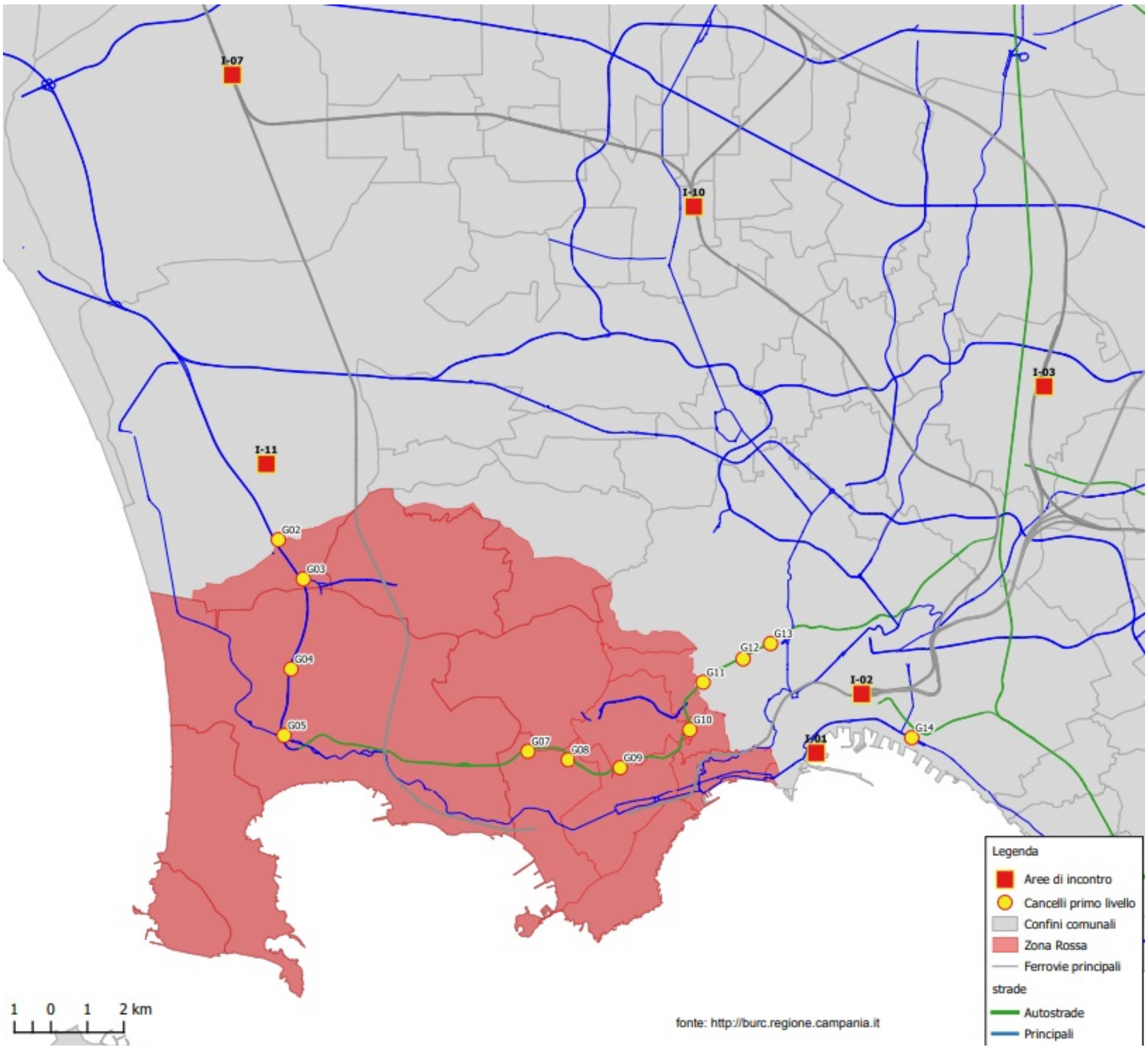


Fig.3 The evacuation gates (yellow), meeting areas (red) and main road networks (green and blue) identified by the National Plan in the red zone

First of all, while the emergency planning process at national/regional scale has been underway for about twenty years, with numerous updates, only some civil protection plans at municipal level have been recently approved and some of them are outdated compared to the regional guidelines for emergency planning, to the most recent regulatory innovations introduced by the Civil Protection Code, and to the most recent provisions of the National Emergency Plan for the Phlegraean Fields.

Still, despite the multi-actor nature of the emergency planning process, the involvement of local population is still limited and essentially attributable to the implementation of some information campaigns. This is a not a trivial issue, especially in an area that between the Seventies and Eighties of the last century witnessed a difficult and still largely debated experiences of "forced evacuation". We refer, in particular, to the precautionary measures due to the worsening of the bradyseism phenomenon, which led to the forced removal of the population from the Rione Terra and the historic center of Pozzuoli and to its permanent relocation into new neighborhoods placed at the outskirts of Pozzuoli. These interventions, carried out in the lack of an overall vision of the urban development due to the lack of a municipal masterplan, resulted into significant and long-term social and economic damage for the local population. In particular, the lack of updated spatial planning tools at different scales has led not only to the consequent lack of rules capable of reducing, or at least of not increasing, the exposure and vulnerability of this vast territory, but also to a difficulty in developing an effective cooperation between emergency and spatial planning processes.

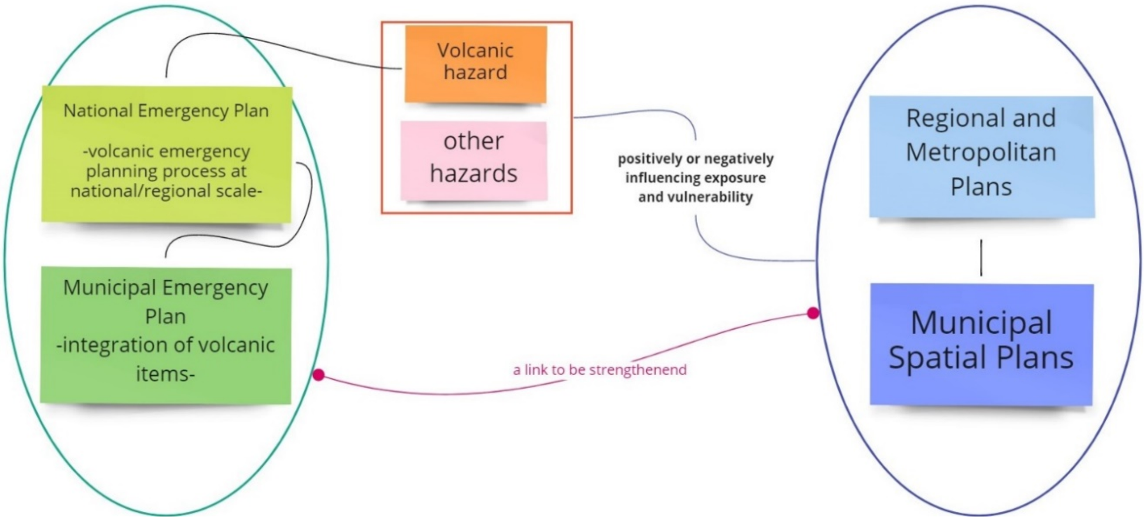


Fig.4 The complexity of a multi-scale and multi-actor decision-making process

To date, in fact, only the municipality of Monte di Procida has a spatial urban plan drawn up after the approval and the update of the civil protection plan.

Summing up, the peculiar context of the Phlegrean Fields clearly highlight the difficulties of building up a multi-scale and integrated decision-making processes. In this area, the complex issue of better cope with volcanic risk requires a close interaction among emergency plans at different geographical scales; moreover, emergency plans at municipal scale have to take into account the multiple hazards affecting this area as well as their likely chains. Finally, emergency planning would largely benefit from a closer integration with planning tools at different scales – so far essentially missing – capable of reducing exposure and vulnerability features of this area to the multiple hazard factors (Fig. 4).

3. How effective are emergency measures in the red zone? A focus on three Municipalities in the Red Zone

As previously highlighted, the lack of effective measures aimed at ensuring a preventive reduction of the multiple risks that the Phlegraean territory is prone to assigns a difficult task to emergency planning, called to set up measures able to face complex risk scenarios, in a territorial context characterized by a high concentration of population (to date the inhabitants of the red zone are about 500 thousand) and assets as well as by a road network not fully adequate to guarantee equal access to the emergency facilities and, above all, to the gates identified by the National Plan for the evacuation of the resident population in case of volcanic eruption.

In order to better understand the main criticalities of emergency planning in the Phlegraean area, a rough evaluation of the effectiveness of the main forecasts of current emergency planning tools has been carried out, with reference to three municipalities totally included in the red zone: Monte di Procida, Bacoli and Pozzuoli. All the three considered municipalities are affected by different hazards: in addition to the likely eruptive scenarios identified by the National Plan for the Phlegraean Fields, they are all classified as zone 2 in the regional seismic classification and characterized by large areas prone to hydraulic and landslide hazards. Finally, as mentioned above, only Monte di Procida has approved, in 2020, the spatial urban plan.

In detail, the attention is here focused on the strategic facilities for emergency management identified by both the National Plan for the Phlegraean Fields and the Civil Protection Plans of the Municipalities of Bacoli, Monte of Procida and Pozzuoli. Taking into account that emergency facilities are closely connected to each other as well to the other elements of the urban system, the following issues have been specifically examined:

- the "safe" location of the emergency facilities as well of the road infrastructure connecting them to the residential areas;

- the accessibility of the waiting areas identified by the Civil Protection Plans and of the evacuation gates identified by the National Plan from the residential areas;
- the redundancy of the roads ensuring both the access of rescuers to the residential areas and the evacuation of these areas in case of hazardous events.

The aforementioned steps have been carried out through a GIS-based analysis. The initial heterogeneous dataset, composed by different sources (Municipal Emergency Plans, National Evacuation Plan, Central Campania Regional Basin Authority, ISTAT census) has been organized in a set of layers and integrated with additional layers deriving from Open Street Maps (OSM) and the GIS of the Campania Region for the road network and from the Corine Land Cover and Urban Atlas for the characterization of urban areas (Fig. 5).

3.1 Is the location of emergency facilities and infrastructure safe?

With reference to the strategic buildings and infrastructures identified by the Municipal Emergency Plans, it is crucial to firstly examine the location of these elements, in respect to the hazard and vulnerability features of the area.

It should be reminded, in fact, that both of them should be located in safe areas: this implies that they should be located in areas which are not affected by any hazard and, especially in case of seismic events, they should be also located in areas not highly vulnerable to earthquake impacts. In the latter case, indeed, the collapse, even partial, of buildings overlooking the waiting areas or the roads connecting emergency buildings and areas with the residential areas could reduce the functionality of these elements, limiting their usability or accessibility.

Since both strategic areas and buildings, and road infrastructures are largely exposed to climate-related events (Markolf et al. 2019), their location has been examined in respect to both the distribution and levels of hydraulic and landslide hazards, as identified by the Central Campania Regional Basin Authority (Fig. 6), both the seismic vulnerability levels of the residential building stock (Fig. 7). As shown in figure 6 all the strategic facilities (strategic operation centers, municipal police offices, health facilities, ports and heliports, etc.) are located outside the areas prone to hydraulic and landslide hazards, except some waiting, reception and gathering areas, even though all of them are located in areas characterized by low levels (P1) of hydraulic or landslide hazards (Fig. 6).

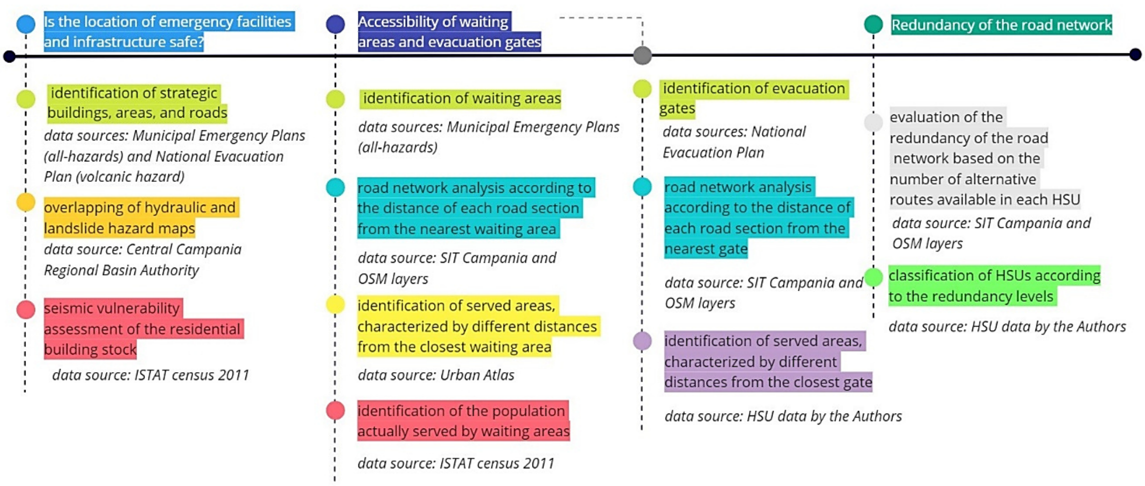


Fig.5 The methodological steps

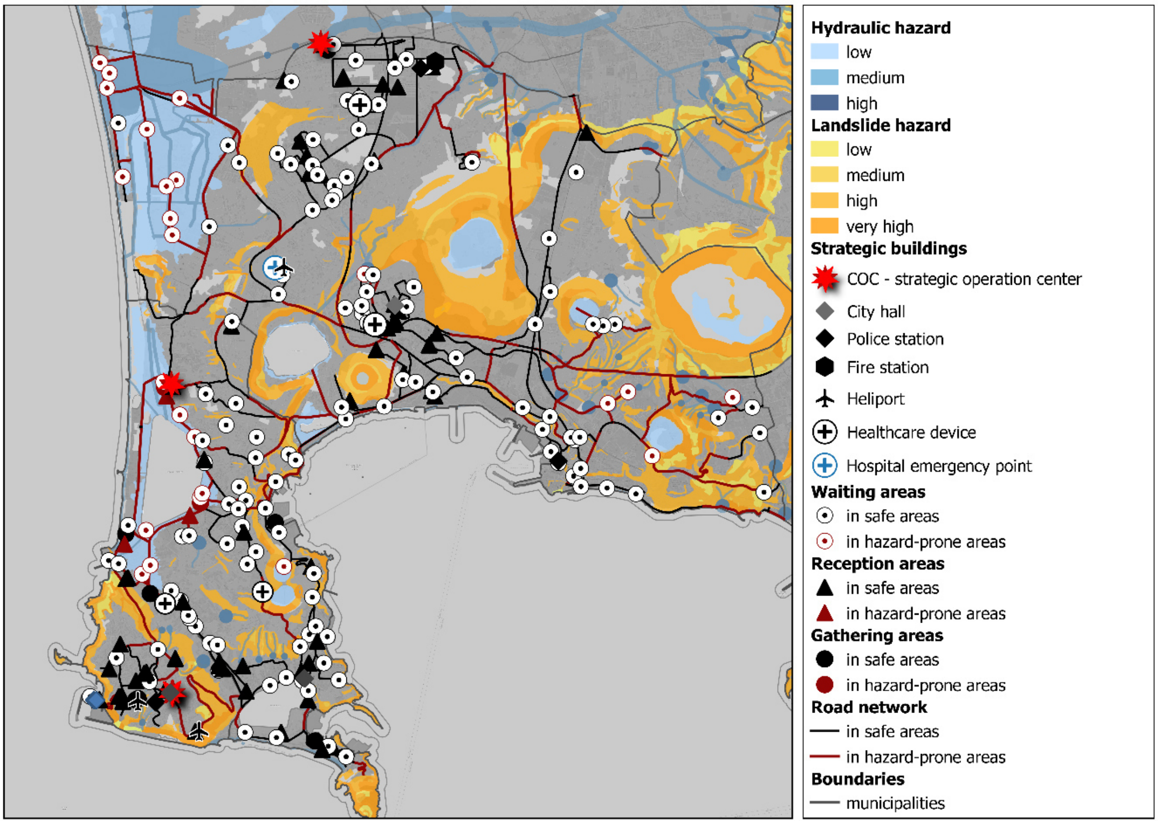


Fig.6 Location of emergency facilities and infrastructure and hydraulic and landslide hazard levels

Although for strategic facilities the prerequisite of a safe location can be considered almost totally satisfied, focusing on the emergency road network, this prerequisite is only partially satisfied: almost 50% of the road network crosses, indeed, areas prone to hydraulic or landslides hazard.

Another aspect that deserves attention is the location of strategic buildings, areas, and infrastructure in respect to the seismic vulnerability levels of the urban fabrics. To this aim, the whole territory of the three considered municipalities has been subdivided into homogeneous spatial units (HSUs), obtained through the overlapping of three basic layers: ISTAT census units, land uses (as defined by the Corine Land Cover) and hazard levels, namely hydraulic and landslide hazard levels, being the whole territory prone to seismic and volcanic hazard. Then, the seismic vulnerability of each HSU has been assessed, following the methodology proposed by the Technical Directives provided by the Tuscany Region[5] for carrying out geological, hydraulic and seismic surveys. Despite the numerous methods proposed for the assessment of the seismic vulnerability of the building stock, also based on census data (Cacace et al. 2018), the selected methodology allows obtaining a seismic vulnerability index through an expeditious procedure, based on parameters that can be easily measured through data provided by ISTAT census for the residential building stock (Bacci and Di Marco, 2019). In detail, the seismic vulnerability index for each HSU has been obtained through the following parameters:

- the period value (Vp);
- the building materials' value (Vb);
- the height value (Vh);
- the seismic classification index (Ic);
- the urban density index (Id);
- the construction type index (It).

5 Annex A to the Regional Resolution 31, 20/01/2020. Available at: https://www.regione.toscana.it/documents/10180/24616464/Delibera_n.31_del_20-01-2020-Allegato-A.pdf/04f0fce0-61c8-fe48-dcc3-b90d1b818e89?t=1585748800829 [Accessed 3/12/2020]

The period value (Vp) represents the percentage of residential buildings built in each considered period, multiplied by a defined coefficient, with respect to the total number of residential buildings in each HSU. The value is calculated as follows:

$$Vp = \frac{100(E8+E9)+65(E10+E11)+35(E12+E13)+15(E14+E15+E16)}{100(E3)} \quad (1)$$

where the Ex values represent the data provided by ISTAT for the construction periods of the residential buildings and the numerical values represent the coefficients related to each construction period.
The value (Vb), which indicates the percentage of buildings in material other than reinforced concrete with respect to the total, is obtained as follows:

$$Vb = \frac{1-E6}{E3} \quad (2)$$

where E6 is the number of residential buildings made of reinforced concrete and E3 is the total number of residential buildings in each HSU.
The height value (Vh) represents the percentage of residential buildings with the same number of floors, multiplied by a coefficient, compared to the total of residential buildings and it is calculated as follows:

$$Vh = \frac{0.50(E18)+0.75(E19)+0.875(E20)}{E3} \quad (3)$$

where the Ex values represent the data provided by ISTAT[6] for the number of floors of residential buildings and the numerical values represent the coefficients, assigned in relation to the different numbers of floors.
The seismic classification index (Ic) is introduced by the adopted methodology to increase vulnerability values in those areas where, before 2003, the seismic class was lower than current one. For these areas, the Ic index is equal to 1. In the case study area, since all the selected municipalities were classified as seismic zone 2 also before the 2003, the Ic index is considered equal to 0.
The urban density index (Id) that, based on the adopted methodology can be defined according to the locality code assigned for each census unit by the ISTAT census equal to 0 for main and secondary urban settlement and for industrial areas and equal to -2 for isolated buildings, is here referred to the land uses classified by the Corine Land Cover: in detail, it is equal to 1 if the HSU is classified as urban area and equal to 0 in the other cases.
Similarly, the construction type index (It), which in the adopted methodology, according to the locality code assigned for each census unit by the ISTAT census, is defined equal to 1 for industrial areas in order to take into account the higher vulnerability of long-span buildings, is here posed equal to 1 in case of HSU classified as industrial by the Corine Land Cover and equal to 0 in other cases.
Summing up, each HSU has been classified according to the value assumed by the seismic vulnerability index obtained as follows:

$$Iv = \frac{Vp^2+Vb^2+Vh^2+Id^2+It^2}{Vp+Vb+Vh+Id+It} \quad (4)$$

where all the considered indexes vary between 0 (minimum vulnerability) and 1 (maximum vulnerability).
As shown in Fig.7, the seismic vulnerability analysis of the urban fabrics allows identifying a significant percentage of strategic facilities located in areas characterized by high levels of seismic vulnerability and a very high percentage, more than 65%, of road sections crossing highly vulnerable areas.

[6] The description of the data provided by ISTAT for each census unit is available at: https://www.istat.it/it/archivio/104317 [Accessed 3/12/2020]

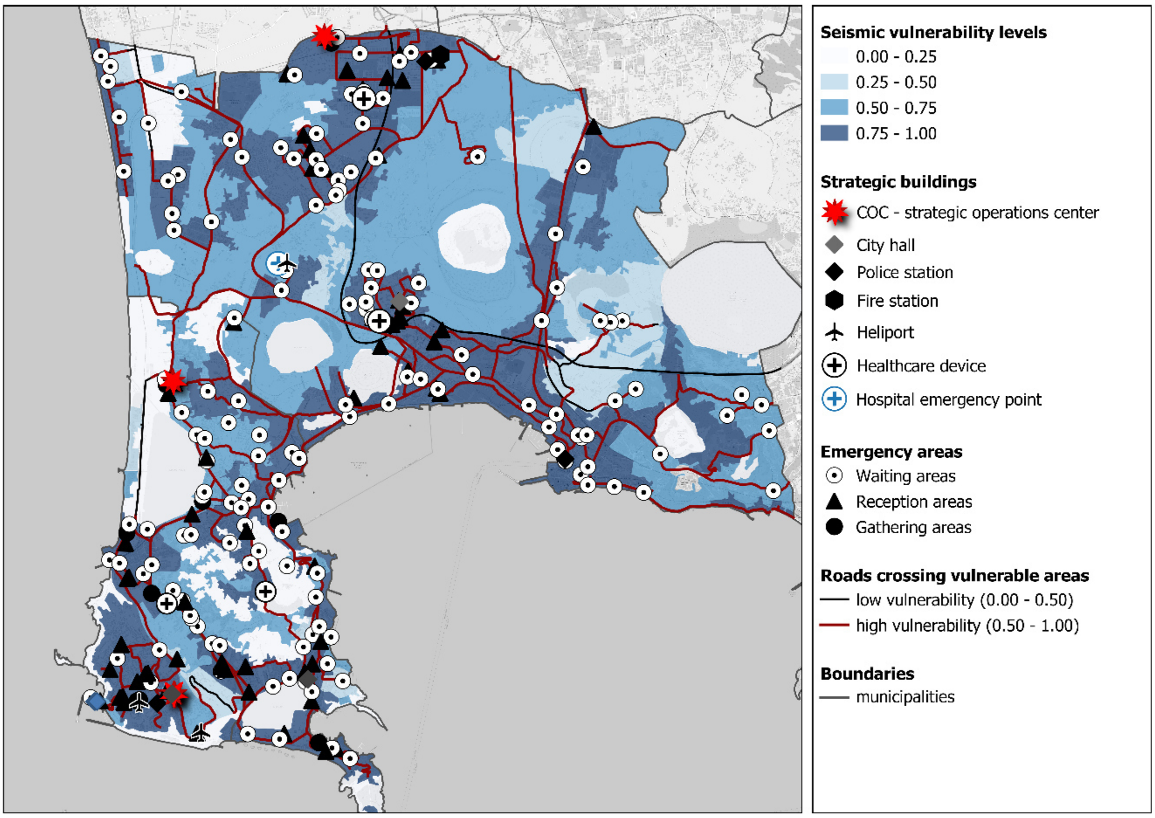


Fig.7 The location of emergency facilities and infrastructure in respect to the different levels of seismic vulnerability of the urban fabric

With reference to the effectiveness of emergency management, these analyses reveal significant criticalities both in terms of "safety" of the identified waiting areas, and in terms of effective accessibility of or from emergency facilities (Francini et al., 2018a).

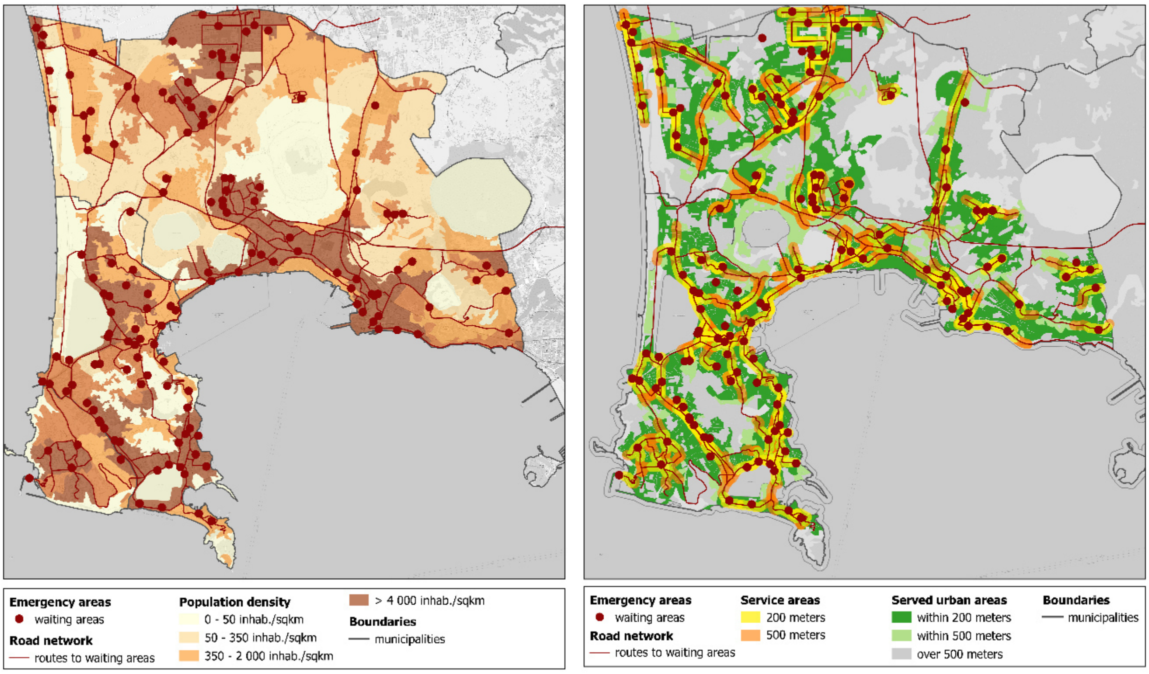
3.2 Accessibility of waiting areas and evacuation gates

Another key point to evaluate the effectiveness of current emergency planning refers to the accessibility of both waiting areas, identified by the civil protection plans, and evacuation gates, identified by the Evacuation Plan.

With reference to the waiting areas, it is useful to remind that they represent the first meeting areas in case of hazardous events that, as mentioned above, have to be spread throughout the municipal territory: they should be located in safe areas and easily accessible through safe, and generally pedestrian, paths. Their size depends on the number of inhabitants and on the accommodation capacity of each area: they are generally used for a relatively short period of time, as they are intended to provide population with the first information on the event and the first aids, while waiting for the preparation of the larger reception and gathering areas.

In the selected case study areas, the civil protection plans currently in force identify 147 waiting areas: most of them are squares, public and private parking lots and open spaces placed along the road network (Fig. 8a).

The accessibility of each waiting area has been firstly calculated along the roads. Hence, the road network has been divided into sections according to the distance of each road section from the nearest waiting area (service areas) (Fig.8b). Then, in order to assign a level of accessibility to each residential area and due to the number and spread of the waiting areas, the whole considered territory has been divided into units significantly smaller than the HSUs previously considered.



(a) (b)

Fig.8 (a) Population density and distribution of the waiting areas and (b) waiting areas' accessibility

These units have been defined according to the partition proposed by Urban Atlas. Hence, the level of accessibility of each unit has been calculated based on the accessibility level of the road sections adjacent or intersecting the unit itself.

Following this procedure, the whole territory has been classified into three group of served areas, characterized by different distances from the closest waiting area (Fig.8b):

- areas that have a distance minor than 200 mt;
- areas that have a distance between 200 and 500 mt;
- areas that have a distance greater than 500 mt.

It is worth emphasizing that a distance of 500 mt can be walked, in peacetime and by a person in normal conditions, in about 6-8 minutes on foot: hence, the areas that are far more than 500 mt from the nearest waiting area have to be considered not adequately served.

Finally, to estimate the population actually served by the waiting areas, the perimeters of the census units provided by ISTAT (2011), have been overlapped to the served areas. By considering a uniform distribution of the population on the surface of each census unit, the population living in the served areas whose distance from the waiting area is less than 200 mt is about 65%, while about the 15% of the population live in areas showing a distance from the waiting area between 200 and 500 mt.

This rough estimate allows highlighting that the number and distribution of the foreseen waiting areas can be considered adequate to serve the majority of the population. However, an in-depth evaluation of the effectiveness of these areas should take into account, besides their accessibility, also their safety, already discussed above, and their capacity to accommodate the served population, which has not been evaluated in this study.

With reference to the evacuation gates, it is worth reminding that the Evacuation Plan for the Phlegraean Fields takes into account both autonomous and assisted evacuation and that in a time span of 72 hours, the population should reach, or should be accompanied to, the meeting areas located outside the red zone (Fig.3), through the first level gates identified by the Plan itself.

The closest gates for evacuating the three considered municipalities are: the G03 located in Giugliano, the G04 and G05 located in Pozzuoli and the G07, placed at the Agnano exit of the urban highway in Naples (Fig.9). With respect to these gates, the travel distances from each residential area have been calculated.
In detail, following the methodology previously adopted in respect to the waiting areas, the accessibility of each gate has been firstly calculated along the roads. Hence, the road network has been divided into sections according to the distance of each road section from the nearest gate.
The provided classification refers to both spontaneous and assisted evacuation, which should occur through shuttles and buses departing from the waiting areas identified by the civil protection plans and shown in figure 9.
Then, in order to assign a level of accessibility to the different residential areas, we referred to the HSUs previously considered. The level of accessibility of each unit has been calculated according to the accessibility level of the road sections adjacent or intersecting the unit itself.
Based on this procedure, the whole territory has been classified into three group of areas characterized by different distances from the closest gate (Fig. 9):

- areas that have a distance minor than 2 km that, considering a speed of 50 km/h, can be traveled by car in about 2,5 minutes;
- areas that have a distance between 2 and 5 Km (6 minutes);
- areas that have a distance greater than 5 Km.

The maximum distance has been calculated in 10 km: hence, at a speed of 50km/h, the most distant residential areas could reach the closest gate in about 12 minutes. However, travel times have been calculated with reference to the maximum speed limit in built-up areas (50 km/h), without taking into account nor the congestion phenomena that could occur during the evacuation, slowing down the evacuation process, nor the features of each road section (slope, width, etc.).

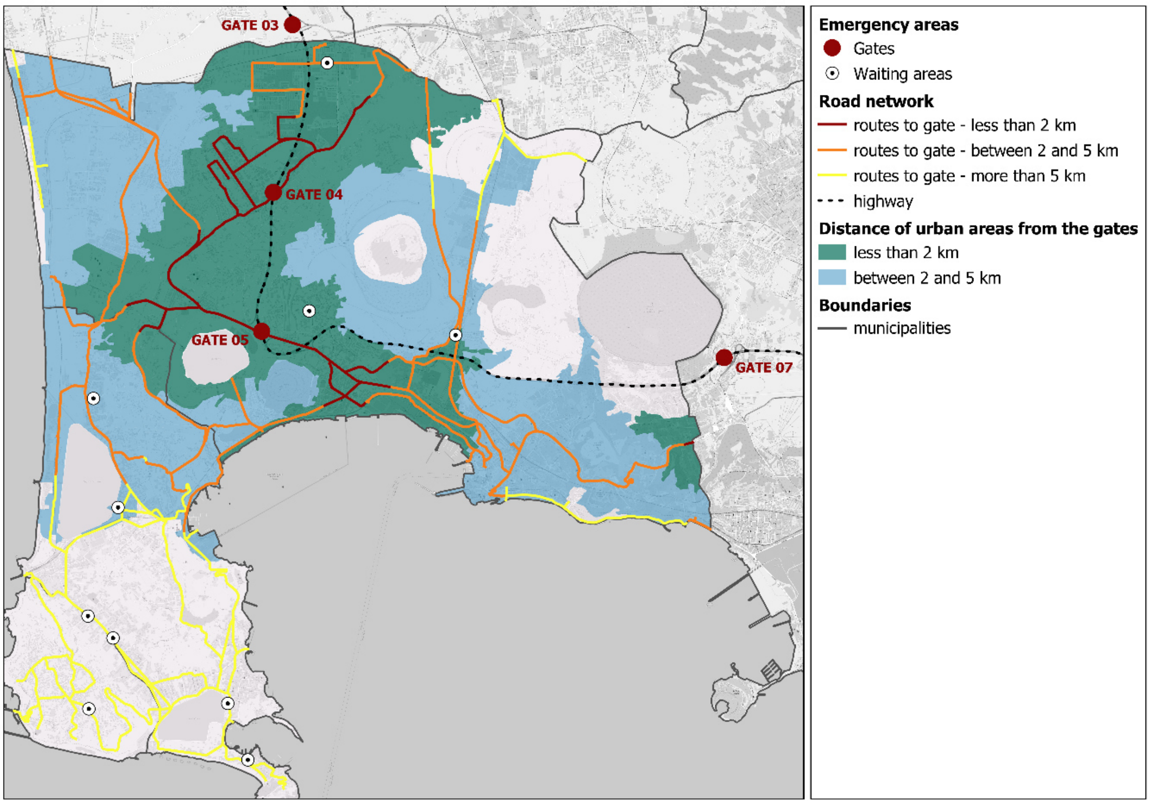


Fig.9 Evacuation gates' accessibility

3.3 Redundancy of the road network

Redundancy is one of the characteristics that may contribute to increase resilience of urban systems in the face of hazardous events (Bruneau et al., 2003; Papa et al. 2015). Therefore, the capacity of road infrastructures to effectively perform their functions in case of emergency has been here evaluated also in respect to their redundancy (Tilio et al. 2012), interpreted as the presence of alternative routes in respect to those identified by the emergency planning tools. In the red zone, indeed, each municipality had to identify the main access routes to the gates, in accordance with the provisions of the Evacuation Plan, providing for a temporal staggering of the flows and taking into account the flows due both to the autonomous and assisted evacuation. Moreover, each Municipality had to consider both the flows of the resident population both those coming from other municipalities. Due to the location of the gates, which are not equally distributed in each Municipality, the flows from Monte di Procida burden on those of Bacoli which, in turn, partially burden on those of Pozzuoli.

Thus, with respect to the general accessibility to and from strategic facilities examined in sub-paragraph 3.2, here the focus has been shifted to the number of routes, alternative to the main evacuation route, within each HSU, delimited as described in subparagraph 3.1 (Fig.10). In detail, to evaluate the redundancy of the road network, the number of alternative routes (Ar) available in each HSU has been calculated as follows:

$$Ar = n - 1 \tag{5}$$

where n is the number of nodes of the road network. Hence, each HSU has been classified according to three levels of redundancy:

- areas where no alternative routes are available;
- areas characterized by one or two alternative routes in addition to the main one;
- areas where more than two alternative routes are available.

Hence, the higher is the number of alternative routes, the lower is the possibility that a given area remains isolated in case of obstructions or congestion of the main route, even though the difficulty of managing traffic flows at intersections might partially increase.

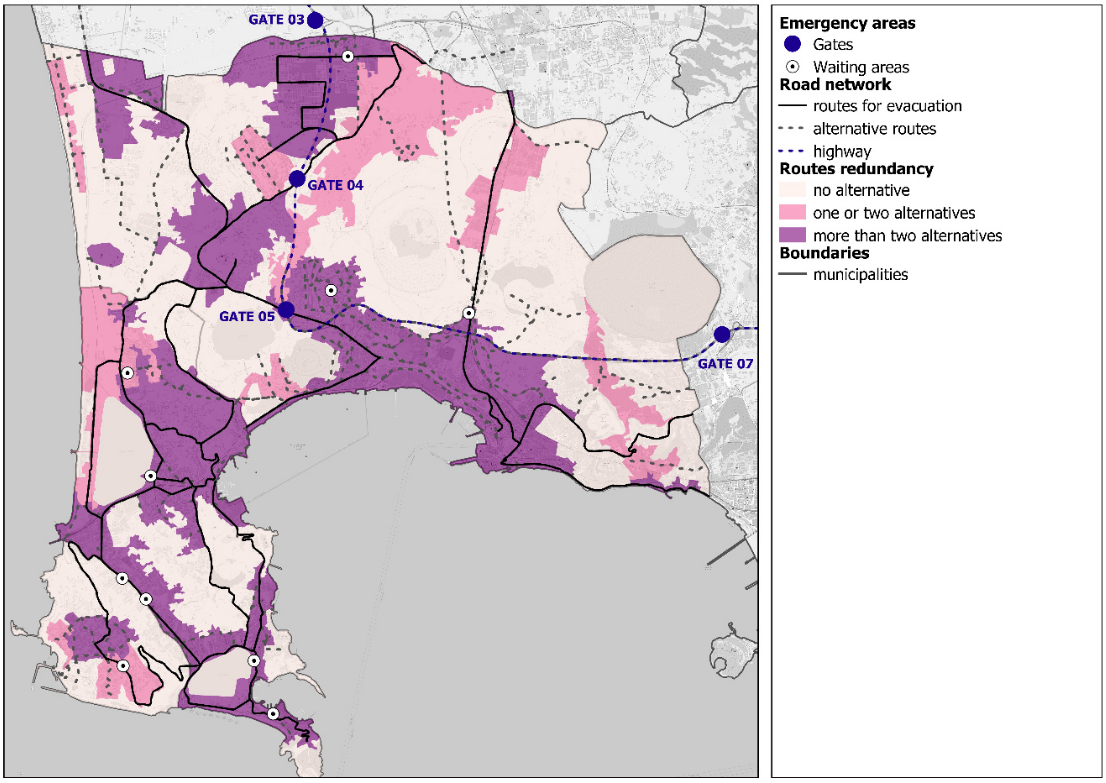


Fig.10 Redundancy of the road network

4. Discussion and Conclusion

The three-steps analysis carried out to evaluate the effectiveness of the complex system of strategic facilities (buildings, areas) and infrastructure that current emergency planning tools rely on sheds light, first of all, on the importance of adopting a systemic, multi-risk and multiscale perspective in emergency planning. The adequacy of the emergency network, crucial to ensure an effective response of territorial systems in the face of hazardous events, depends indeed both on the 'safety' of each element, in a multi-risk perspective, both on the relationships among the different elements of the network and among these elements and the urban tissues they belong to.

Moreover, the case study and in particular the close interdependency between the considered Municipalities of Bacoli and Monte di Procida clearly demonstrate the importance of a multiscale approach, capable of grasping the relationships between the individual elements of the emergency network both within each Municipality and in the wider territorial context that each Municipality belongs to.

Furthermore, the numerous criticalities related to the safe location as well as to the accessibility of strategic facilities and infrastructure in the case study area highlight the need for improving current cooperation between emergency and spatial planning tools. The latter could provide, indeed, a significant contribution, on the one hand, to preventively reduce the multiple risks these territories are exposed to – by avoiding, if possible, the occurrence of hazards or minimizing their impacts by acting on exposure and vulnerability – on the other hand, to improve current road network by enhancing, directly or indirectly, both its accessibility and redundancy even in the emergency phase. The analyses carried out on the case study area clearly highlight that risk informed spatial planning tools could positively affect the effectiveness of current emergency plans. Spatial plans at different scales could, for example, favor a more balanced distribution of activities, which might result into a reduction of flows along the most congested sections of the emergency road network, or could promote seismic adaptation of the existing building stock in the most critical territorial units, where the key elements of the emergency network are located.

Unfortunately, as mentioned above, to date only Monte di Procida has approved a spatial plan, while Bacoli has approved only a preliminary plan and Pozzuoli has a spatial plan approved in 2002, which is actually outdated. Hence, current relationships between urban and emergency planning tools can be examined only with reference to the municipalities of Monte di Procida and Bacoli.

Monte di Procida is a paradigmatic example of misalignment among different planning processes within the same municipality. On the one hand, in fact, it is one of the few municipalities in the Campania region that approved, more or less in the same time span, both the spatial urban plan and the civil protection plan. On the other hand, the analysis of the two planning tools does not reveal an explicit attempt to integrate them, even though there were the conditions for a full integration, since the civil protection plan was approved in 2017 and the spatial plan in 2020. Furthermore, the spatial plan at stake includes a detailed analysis of its compatibility with all the planning tools currently in force in the municipal area: the Extract Plan for Hydrogeological Risk, the Territorial Landscape Plan, and the Territorial Coordination Plan of the Metropolitan City of Naples, although the latter has been only adopted in 2016, but not yet approved.

Despite the lack of explicit references to the civil protection plan, the spatial plan of Monte di Procida devotes large attention to risk issues, by providing an in-depth analysis of the hydraulic hazard, with a discretization of the single homogeneous zones affected by the hydraulic hazard and a report related to the interventions for the hydrogeological safety of the sea ridges.

With respect to the volcanic risk, the spatial plan does not include specific strategies aimed at reducing current residential density, such as incentives for relocation in safer or more accessible areas. However, in accordance with the rules of the landscape plan in force, which do not allow any increase in the overall settlement load, the plan does not include new residential areas.

As regards the road network that, as highlighted above, shows numerous criticalities, the spatial plan explicitly addresses some of them, such as the numerous interruptions that currently characterize the road network, the high levels of congestion, the difficulties to reach the extra-municipal road network, and defines some actions aimed at completing the road networks and eliminating the dead-end roads. Although there is no correspondence between the indications provided by the spatial plan and related to the roads to be adapted and to the new roads and those provided by the civil protection plan in respect to the roads to be strengthened and adapted, the combination of the actions envisaged by the two plans could lead to an overall reduction of traffic congestion in some critical points and to a higher redundancy of the existing road network.

However, it has to be clearly remarked that the effectiveness of the road network of Monte di Procida is strictly dependent, on the one hand, on the morphological features of the municipal territory itself, which determine its tortuosity and the reduced width of numerous road sections; on the other, on the close interdependency between Monte di Procida and Bacoli, through which the main access and exit roads to and from Monte di Procida pass.

In the Municipality of Bacoli, the civil protection plan was approved in 2016 and updated in 2018, while the preliminary spatial plan, carried out in 2015, was revised in 2017. Here, the need to better cope with volcanic risk by improving, expanding and adapting the road network also for improving its functionality during the emergency phase was already highlighted by the 2015 preliminary plan.

The 2017 revision of the plan has led to a realignment of the planning strategies with the provisions of the civil protection plan approved in 2016. Thus, current preliminary spatial plan devotes large attention both to the risk management, namely to the hydrogeological risk management, and to the improvement of accessibility and evacuation routes. In detail, it recognizes the criticality of the interconnections with the municipality of Monte di Procida, but also the opportunities arising from a better integration between the strategies of the two municipalities for improving the key points for both accessibility and exodus in case of emergency. Furthermore, current preliminary plan highlights the need for improving the safety of the whole municipal area, and in particular of the road network, with respect to hydrogeological risk. The strategies concerning the road network provide, therefore, solutions addressing the reduction of both current road network congestion, which also depends on the significant touristic flows that reach high peaks in some periods of the year, and hydrogeological risk conditions that characterize some of the escape routes and emergency areas identified by the civil protection plan.

Summing up, also the most recent spatial urban plans, despite showing a higher attention than in the past to risk reduction and emergency management issues, do not include any explicit reference to the civil protection plans, highlighting that an effective integration between emergency and spatial planning processes, even when they develop almost contemporarily, is still far to be achieved. Unfortunately, emergency planning still represents a sectoral planning process, not yet interpreted as a further and crucial dimension of the overall urban planning process.

Authors' contribution

Although this paper is the result of a common work, AG supervised the entire work and wrote section 1. AG and GG wrote section 2; GL was responsible of data elaboration and representation in GIS environment and wrote section 3; AG, GG and GL wrote section 4.

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Fig. 5: Authors' Elaboration;

Fig. 6: Authors' Elaboration on contents of Municipal Emergency Plans and Central Campania Regional Basin Authority;

Fig.7: Authors' Elaboration on contents of Municipal Emergency Plans and ISTAT census 2011;

Fig.8 (a) and (b): Authors' elaboration on contents of Municipal Emergency Plans and ISTAT census 2011;

Fig.9: Authors' elaboration on contents of Municipal Emergency Plans and Evacuation Plan;

Fig.10: Authors' elaboration on contents of Municipal Emergency Plans and Evacuation Plan;

Tab.1: Moccia, 2018 and Authors' updating (December 2020) based on information provided by the websites of each Municipality and of Campania Region;

Tab.2: Authors' elaboration based on information provided by the websites of each Municipality and of the Campania Region.

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Territorial aspects of emergency plans for dams. The case study of Lombardia Region

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Abstract

A directive of the Prime Minister in 2014 required regions where large dams are located to develop emergency plans to coordinate efforts and resources in case of sudden unexpected release or the worst case of partial or total collapse. The risk for downstream communities and assets is clearly a significant one, as many dams have been built some decades ago and there are evidences of changing trends in meteorological and climate relate extremes that are particularly dangerous for mountain relatively small catchments. In developing such new generation plans, the definition of risk scenarios describing territorial dynamics and features (in terms of hazard, exposure and vulnerability) provides a quali-quantitative representation of potential damages and losses that may occur in case downstream settlements and infrastructures are affected or, even worse, caught by surprise by an incident. On the basis of a recent experience carried out within a collaboration framework with the Lombardia Region, the paper provides indications on the current problems and opportunities related to risk management, emergency preparedness and planning in presence of dams considering technical, social and public policies decision-making issues as key. The paper provides initial reference to the national and international experience on the topic to discuss more in depth how territorial aspects have contributed substantially to shape emergency plans for dams and what are the consequent impacts on ordinary urban and regional plans at different scales.

Keywords

Urban and Emergency planning; Dams; Disaster risk impact assessment.

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1. Introduction

Currently, the presence of a watercourse artificial barrier as a dam must be considered in a social-economical perspective for the value it creates for the region and its inhabitants. On one hand, it represents a territorial resource as strategic infrastructure for the management and sustainable use of water resources in various sectors (i.e. civil, energy, agricultural, zootechnical, industrial) also in consideration of the European (and national) energy targets for the use of renewable and carbon free sources (Directive 2009/28/EC). On the other hand, it represents a potential threat to the safety and protection of downstream human lives, properties and the environment that could be affected by the flood wave as revealed during many past national and international disasters causing enormous damage and hundreds of deaths. In general, the risk due to the presence of a dam in a given territory ("dam risk") is defined as the occurrence probability of floods damaging the dam downstream valley and its elements in consequence of: 1) the collapse/failure of the main/ancillary structures of the artificial barriers for structural reasons or induced by external phenomena (i.e. earthquakes, landslides) ("dam break") or 2) sudden release of water required by large volumes of material (i.e. water, snow, rock) brought in by meteorological events or landslides or by very intense precipitation causing the reservoir to reach its safety limits.

Considering that "dam risk" may be determined by both controlled and uncontrolled phenomena, in order to minimize the associated territorial damage, in addition to safety control programs carried out by the dam's owner to monitor its structural behaviour, it's also fundamental to act on the capacity of social, economic and environmental systems in order to make them prepared in case of crisis in particular by prevention measures (both structural and non-structural) (Sendai Framework for Disaster Risk Reduction 2015-2030). In this sense and at different territorial levels, Civil Protection planning (or Emergency Planning) is recognized as a non-structural prevention activity, a set of strategies and actions implemented to mitigate negative impacts, helping communities to face and overcome emergency situations (Menoni, 2013). Overcoming past approaches that considered emergency plans as mainly aimed at organizing resources and operative procedures, the current approach attributes a more active role to a large variety of public authorities and subjects involved in the territorial risk prevention at different albeit integrated levels. This is a crucial point considering that territorial risk conditions may depend not only on the presence and structural behaviour of dams but also on the vulnerable land uses and/or on the geo-morphological features of the catchment downstream with several streams that can be also become dangerous under the same meteorological conditions that may cause dams' failure. In this regards, urban planning is also playing a fundamental role in the physical development of urban settlements ensuring public environment protection; then stakeholders must be involved on the basis of their competencies in the implementation of strategies and actions at different territorial scales to mitigate negative impacts in case of "dam risk" taking into consideration the characteristics of dam downstream valleys. Moreover considering the dynamic nature characterizing the current territorial processes, Emergency Planning must be considered as an operational process (Perry and Lindell, 2003) with a dynamic structure whose contents must be constantly updated both during the ordinary period (or peacetime) and in consideration of lessons learned over time (i.e. during emergencies and/or periodic exercises). On the basis of a recent experience carried out within a collaboration framework between Lombardia Region and Milano Politecnico aimed at supporting and developing methodologies and frameworks for civil protection planning in areas at "dam risk", the paper provides indications on the current problems and opportunities related to risk management, emergency preparedness and planning in presence of dams considering technical, social and public policies decision-making issues as key. In particular, starting from an initial reference to the national and international framework about normative and operative requirements for the Emergency Planning in presence of dams with focus on the Lombardia Region experience, the paper discuss more in depth how territorial aspects have contributed substantially to shape emergency plans.

2. Normative and operative requirements for the Emergency Planning in presence of dams

In territories where dams are located, in addition to technical safety requirements for the design, construction, operation, monitoring and inspection of dams aimed at limiting the probability of their failure, civil protection provisions (i.e. Emergency Plans including warning, alert and recue systems) are adopted to protect properties and human lives and mitigate the negative consequences of potential events. In some countries in Europe (i.e. Finland, Norway, Portugal and Spain) both safety control requirements and civil protection measures are graded according to the evaluation of consequences due to dam failure (hazard classification); in other countries (i.e. France, Italy and Switzerland) the selection of normative and operational requirements depends on the classification of dams according to their size (i.e. dimensions of the dam body and/or reservoir capacity). So with a different approach on the topic, each country defines its own specific dam safety legislation regulating different issues as a) dams subjected to regulation, b) entities concerned, c) dams projects (construction, operations and decommissioning) and d) Emergency Planning for the protection of the population (ICOLD, 2018).

The development and the implementation of Emergency Planning procedures are recognized worldwide as the key issue to minimise flood impacts. It is a common practice to divide the Emergency Plan into some fundamental components: 1) Identification and evaluation of potential risk conditions, 2) Risk emergency management (including rescue and evacuation of the population at risk), 3) Information, alert and warning system and 4) Training. A key element of the latter activities is the creation of inundation maps (carried out using numerical dam-break flood analysis) always required to represent the potential flood risk areas and organize accordingly operative procedures. In general, the legislation does not set technical requirements for this analysis but in some cases specific guidelines are available; for exmple in France, Portugal and Switzerland risk zones are identified depending on the time of flood wave arrival (ICOLD, 2018). Then in addition to downstream valley risk zoning, early warning system is another key element playing an important role in crisis management as non-structural measure intended - by the installation of warning signs along the stream and/or downstream the dam - to alert in case of sudden increase of the water flow related to the opening of the dam outlet works. Currently some European countries (i.e. France and Italy) have installed warning systems in the form of sirens at the dam site that are under the direct control of the dam owner responsible for the installation, to be activated before any voluntary opening of the outlets. In Italy, there is a mandatory procedure to issue an audible wail whenever spillway gates are operated (Ministry of Public Works Circular n. 1125 of 28 August 1986). Some other countries (i.e. Netherlands and Portugal) consider warning to the population at risk as a main responsibility for the civil defence authority and recommend for those most vulnerable areas a shared responsibility, between the dam owner and the civil defence authority. Public administrations at different scales hold the main responsibility (i.e. national, regional or local) in controlling the dam safety and protecting the populations and the assets downstream. However, an important role is played also by exposed communities, that must be appropriately informed about the plan and trained on life saving behaviours. Risk communication and training are key components of Emergency Preparedness. In fact, in many countries tabletop exercises are done annually. The latter can be "functional exercises" simulating different events and performing a role-play with participants seated in separated rooms to simulate their operation centre or "full scale" exercises where participants play their role "at site" in a most realistic environment. Starting from the definition of the main components and key elements of the Emergency Planning at European level, the next paragraph is aimed to present and describe the Italian framework in terms of normative and operative requirements for the Emergency Planning activities in presence of large dams[1].

2.1 The Italian framework

With regard to dam safety and civil protection requirements, the Italian legislation is particularly complex. In addition to several general and detailed technical norms (both regulatory and administrative), there are a number of other provisions regulating the activity of the National Supervisory Authority and directives related to environmental and civil protection purposes.

At the national level, in addition to the Legislative Decree n. 1 of 2 January 2018 "Civil Protection Law" defining the civil protection functions aimed at protecting human life, urban assets and settlements also in case of "dam risk", the Directive of President of the Council of Ministers published on 8th July 2014 providing Guidelines for Civil Protection Activities in Areas Exposed to Large Dams (*Indirizzi operativi inerenti l'attività di protezione civile nell'ambito dei bacini in cui siano presenti grandi dighe*) (DPCM 2014) represents the current legal obligation for the management of emergency situations in territories where large dams are located. This Directive establishes updated conditions to activate alert phases for dam safety and management of downstream hydraulic risk and the shared responsibilities among institutional stakeholders involved in Emergency Planning activities. The Civil Protection Document (in Italian *Documento di Protezione Civile*, DPC) at the Prefecture level and and the Dam Emergency Plan (in Italian *Piano di Emergenza Diga*, PED) at the regional level are the two pillars of the entire process. The former is prepared by the Technical Office of Dams (in Italian *Ufficio Tecnico delle Dighe*, UTD) with the technical support of the Directorate General for Dams, the hydraulic authority, the Department of Civil Protection (at national and regional level) as well as the dam owner providing and is approved by the Prefecture. It does provide all technical information on the dam (and on its reservoir) and alert conditions depending on the type of event (the dam break or the full opening of the dam outlet works)[2] and the state of the dam (normal/limited/experimental operation; out of operation; under construction). The latter PED must be prepared by the Region in agreement with the Prefecture to manage the impacts of full opening of the dam outlet works or by its hypothetical collapse on downstream communities. In particular, the Dam Emergency Plan has to provide 1) the scenarios concerning areas potentially affected by the flood wave, 2) the strategies for dealing with the emergency situation by alert and alarm systems, including preventive safeguards measures, population assistance, 3) the intervention model defining the coordination system with the identification of stakeholders and the organisation of operational centres. Both documents must be continuously updated in relation to dam technical interventions and implemented in consideration of the three-year programme (approved on 30 October 2015) defining the annual level of priority for the updating of DPC of all the Italian large dams[3]. Lastly, the Directive requires that operative indications provided by the Dam Emergency Plan are integrated into the civil protection planning at local scale and tested through periodic exercises (D. Lgs. n. 1/2018, art. 18). In addition to the operative requirements of DPCM 2014, other technical documents are relevant for the Emergency Planning in case of "dam risk" as: 1) the Conditions for Operation and Maintenance Document (in Italian *Foglio di Condizioni per l'Esercizio e la*

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[1] In Italy, the "large dams" subjected to the national Dam Authority are defined by the following dimensional parameters: height H> 15 m, or reservoir volume V> 1.000.000 m3. The dam height is the difference between the elevation of the crest and the elevation of the lowest intersection point between the upstream/downstream face and the ground level. Before 1994, lower dimensional parameters were used (10 m, 100.000 m3).

[2] In case of "dam break", 4 alert phases (pre-Alert, Alert, Danger, Collapse) are defined considering the progressively achievement of more severe structural stress states, or limit states (due to the increase in the level of the reservoir or in case of seismic events); in case of the full opening of the dam outlets, 2 alert phases (pre-Alert, Alert) are defined on the basis of the discharged downstream water flow.

[3] The annual level of priority for the updating of DPC of the 534 large dams located in Italy is so defined: 122 large dams have priority I, 182 have priority II, 216 have priority III and 14 large dams are specific cases for which the updating priority of the DPC has not been indicated as they relate to dams for which construction has not yet been completed and dams out of operation.

Manutenzione, FCEM) defining the monitoring, inspections and surveillance activities to be carried out by the dam owner by the installation of monitoring signs, audible warning devices and hydrometric instruments; 2) the Project of reservoir Management (in Italian *Progetto di Gestione dell'invaso*) for the planning and implementation of the management operations of the sedimented material in the reservoir. About alert and warning systems, some installations have to be carried out by the dam owner at each dam site: a siren that can be heard 1000 m downstream, to be activated before voluntary opening of the gates; alert signs along the river, for ten kilometres downstream the dam, alerting about sudden floods due to water discharge from the dam water level recorder immediately downstream the dam (Ministry of Public Works Circular n. 1125 of 28 August 1986). About the level of dam reservoir silting due to sedimentation of soil and rock particles eroded in the catchment area upstream of the barrier and transported by the tributary waters, flaring, de-graveling and mud removal of the dams must be carried out on the basis of specific management project in order to ensure the maintenance of the reservoir capacity and the protection of the quality of the reservoir water and the receiving water body, as well as to ensure the functioning of the dams' components devoted to intake and discharge (Legislative Decree n. 152 of 3 April 2006; Ministry of the Environment and Land Protection Decree of 30 June 2004).

3. The piloting experience of emergency planning for dams in the Lombardia Region

In the Lombardia Region, Northern Italy, several territories are at-risk considering the presence of 77 large dams located mostly in mountain areas in the provinces of Sondrio, Bergamo and Brescia (Fig. 1) and 5 large dams located in surrounding regions in Italy (Isola Serafini dam in Emilia-Romagna and Brugneto dam in Liguria) or in Switzerland (Poschiavo, Albigna and Lugano dams). Moreover, worst risk conditions and negative territorial impacts may be also determined considering both dams location in the seismic areas (D.G.R. 11 July 2014, n. 2129) and the current dam silting phenomenon. With regard to the first aspect, 3 large dams are located in medium-high seismic probability (Seismic zone 2), 64 are in seismic zone 3 (medium seismic probability) and 10 in seismic zone 4 (low seismic probability). About dam silting phenomenon, a management plan of the reservoir is currently expected for 68 large dams considering that 12% of large dams are subject to a level of silting that is not negligible level and 21% to a significant silting level[4].

Currently a total of 2,000 million m^3 reservoir volume is mainly intended for hydroelectric use (90%) (Lombardia Region, Structure for the management of hydroelectric reservoirs, water utilities and energy networks). With regard to normative and operational requirements for Dam Emergency Planning, currently the Civil Protection Document has been provided for all large dams located in Lombardia Region and for almost all of them, technical studies characterizing the downstream valley risk zoning have been prepared.

About it, the Directorate General for Dams and Water and Electricity Infrastructures (in Italian *Direzione Generale per le Dighe e le infrastrutture idriche ed elettriche*) has provided a specific Webgis application to share - with the National Civil Protection System subjects - the technical information and digitalisation of artificial flood waves studies both in cases of the full opening of the outlet works and of the hypothetical collapse of Lombardia dams[5].

In relation to the three-year programme defining the annual level of priority for the DPC updating also for Lombardia Region large dams[6], first activities aimed to prepare the Emergency Plans of the regional large

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4 The level of dam reservoir silting can be "not negligible" (5-20% and/or with annual silting rate: 0,5-1% and/or trend in dam outlet works silting) or "relevant" (>20% and/or with annual silting rate: > 1% and/or trend in dam outlet works silting). In all the other cases, silting phenomenon is "negligible".

5 Directorate General for Dams and Water and Electricity Infrastructures - Webgis application on technical information and digitalisation of artificial flood waves studies flood waves. Available at website: http://onde.mit.gov.it:8080/mit

6 The annual level of priority for the updating of DPC of the 77 large dams located in Lombardia Region is so defined: 8 large dams have priority I, 30 have priority II and 39 have priority III.

dams started in 2019 in the context of the collaboration experience carried out between Lombardia Region and Milano Politecnico. An Working Group named "DAMS EMERGENCY PLAN - DPCM 8 JULY 2014" was established by the regional Directorate General for Territory and Civil Protection of (Decree of the Director General n. 215 of 11 January 2019, extended by Decree of the Director General n. 4675 of 17 April 2020) in order to define all the subjects involved in the Emergency Planning activities for each large dam located in Lombardia. Currently the PED has been approved for two large dams: 1) Ponte Cola dam in Brescia Province (BS) (Lombardia Region, DGR n. 3405 of 20 July 2020) and 2) Pagnona dam in Lecco Province (LC) (Lombardia Region, DGR n. 3731 of 26 October 2020) (Fig.1).

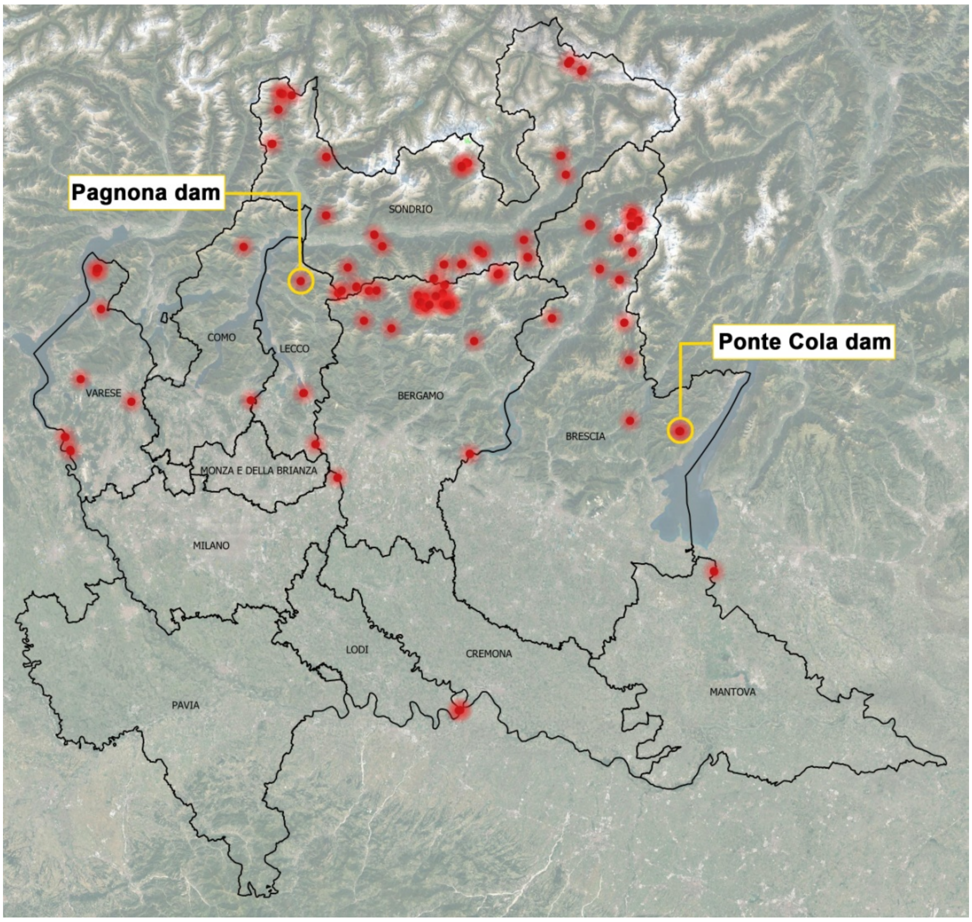
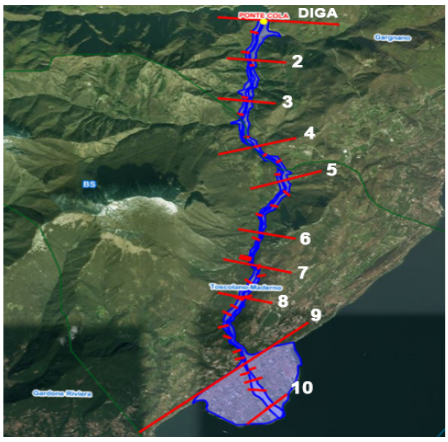


Fig.1 Territorial location of large dams in Lombardia Region.

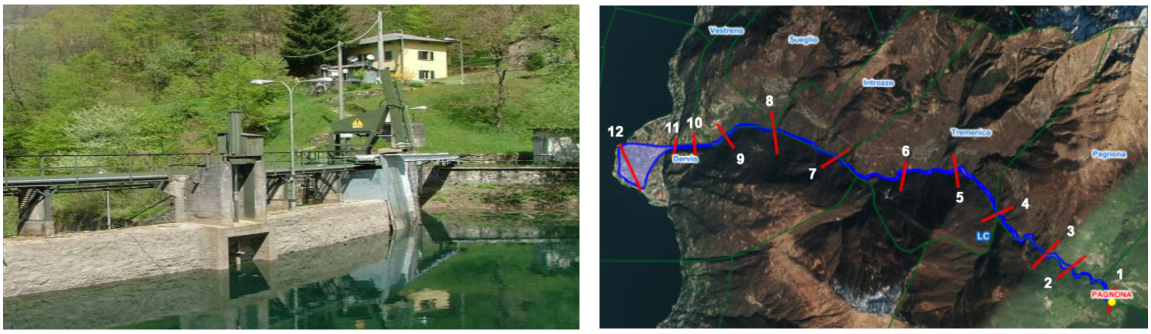
(a)



(b)

Fig.2 Ponte Cola dam: (a) view of upstream face and reservoir and (b) flood area in case of "dam break".

They are artificial barriers with different technical characteristics (with particular regard to the size, volume and state of the reservoir and silting level), located in different seismic hazard zones (Ponte Cola is in zone 2 at medium-high seismic probability; Pagnona is in zone 3 at medium-low seismic probability).
Therefore, the geo-morphological conditions of their engraved valleys and streams are quite similar ending in debris conoids of Garda and Lecco lakes where urban settlements of Toscolano Maderno (BR) and Dervio (LC) are located respectively.
In both municipalities, there are many tourist settlements determining - especially in summer - an increase in number of potentially exposed people, so in the level of territorial exposure and risk consequently to be considered in the Emergency Planning activities. Similarities and differences of the two dams and their own territorial context at risk in which they are located are evident looking at Fig. 2a, b and Fig. 3a, b.



(a) (b)

Fig.3 Pagnona dam: (a) view of upstream face, reservoir and guardhouse and (b) flood area in case of "dam break".

4. The Dam Emergency Planning elements in a territorial perspective

Information and knowledge regarding the territorial features and dynamics of the valleys downstream large dams is key to both plan for emergencies and properly address land use zoning and regulation to ensure sustainable territorial development.
Starting from the review of national and international requirements for the Dam Emergency Planning and on the basis of past working and research experiences on the topic, the developed methodological approach considers emergency planning as a dynamic process producing as an output a document consisting of two main parts:

- Part 1 "Framework of the Plan" aimed at structuring data and information on dams technical details and on their geographical context, also in terms of hazard level, the description of significant past events that affected the community and the assets downstream;
- Part 2 "Operational Plan" aimed at characterizing risk scenarios, delineating operative procedures and actions for the alert, emergency, post-emergency and surveillance phases. In addition to the risk scenarios, this part includes the intervention model, the identification of staging areas for rescuers and resources in case of crisis, the emergency phone book, maps and technical documents related to the dam (i.e. Civil Protection Document).

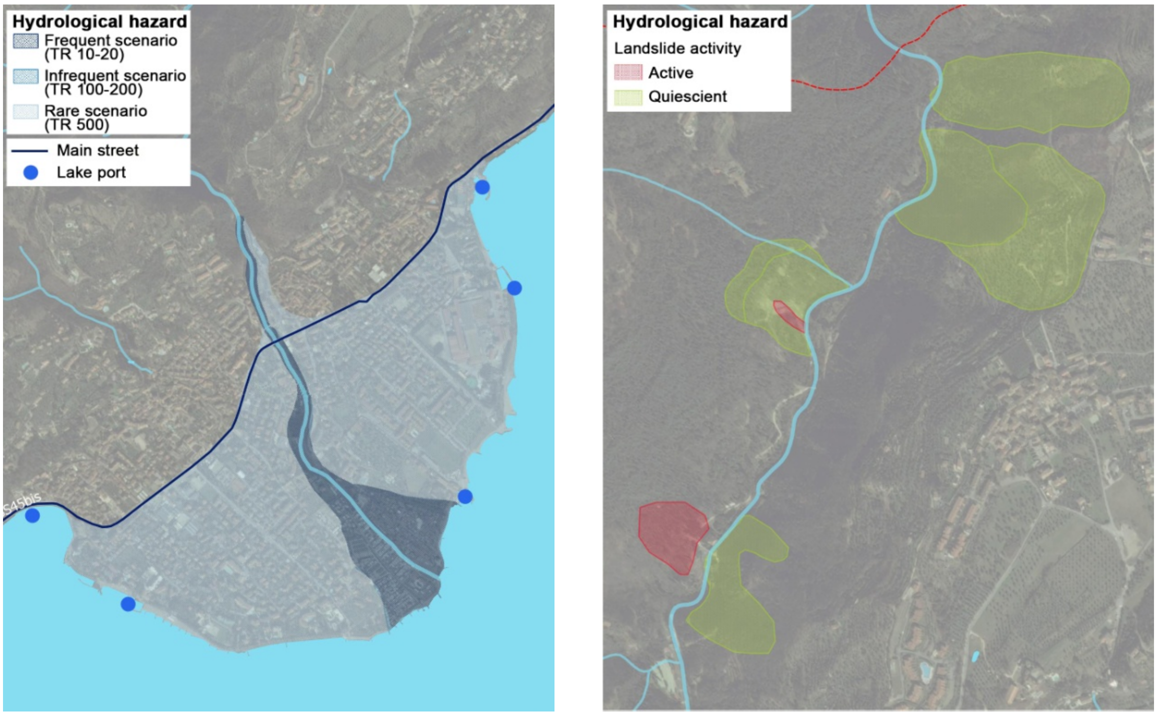
Considering this sequence and studies and research activities carried out to draw up the Emergency Plans of Ponte Cola and Pagnona dams, relevant territorial contents and elements are presented and characterized in the following paragraphs.

4.1 Characterization of the territorial context components

Considering the very basic definition of risk as a probability of damage, where damage is a function of several parameters, including hazard, exposure and vulnerability, all of the latter three must be properly assessed for the purpose of the emergency plan.

Technical information concerning the characteristics of the dam and its reservoir (i.e. outlet works, catchment basin, downstream valley, dam accessibility, silting level) as provided by the main reference documents (i.e. the Civil Protection Document, the Document of Conditions for Operation and Maintenance or the Project of reservoir Management) must be complemented by the analysis of the geographical context considering the exposed social, economic and environmental systems. In order to assess the exposure and vulnerability of downstream communities the following information has been carefully collected and analysed, regarding: administrative and demographic context; orographic, hydrographic and weather-climatic conditions; mobility system and accessibility (by roads, railways, lake, etc.); technological networks; presence of businesses activities and cultural heritage assets, in line also with the requirements of the Flood Directive.

In the specific case of the Emergency Plan in presence of large dams, the analysis of territorial hazards should include the possibility of the simultaneous occurrence of different types of hazard in a territory, such as for example the possibility that consequences of flood wave produced by "dam risk" be combined with the effects determined by earthquakes, landslides or floods. In this regard, the Ponte Cola dam is emblematic as it is located in an area classified in seismic zone 2 (Medium-high seismic probability) and the main urban settlements located in the Toscolano Maderno conoids are potentially affected also by floods caused by Toscolano river flooding (Fig. 4a). Lastly, a partial reactivation of quiescent phenomena as well as numerous new detachments and slope collapses along the valley (known as *Valle delle cartiere*) occurred in recent years (Fig. 4b). The valley is a highly vulnerable territorial area where - in case of extreme weather conditions - buildings, infrastructures and people (especially tourists during the summer) may be affected. Existing hazards may damage strategic or relevant infrastructures for emergency management, limiting the accessibility and making rescue or evacuation extremely challenging.



(a) (b)

Fig.4 Hydrological hazards in Toscolano Maderno (BS): (a) floods and (b) landslides.

Finally, a specific section of the plan has been devoted to envisage the territorial impacts that past events may have today considering the already felt effects of climate change in combination with recent urban and building transformations increasing exposure and vulnerability to floods. In order to feed the estimation of future likely scenarios, information on damages recorded during past natural disasters to different sectors and assets as obtained from the regional RASDA system7and from specific documentation available at local level (municipal or provincial) has been used. Recent events should be integrated in the scenario to be prepared for as they highlight the possibility of phenomena and impacts that may not have been considered insofar. For example, in the case of the Pagnona dam, on June 12 2019 an unusually intense precipitation caused severe flash floods involving significant debris and sediment transport down to the Dervio municipality where they provoked a temporary "dam effect" filling the railway bridge with consequent overflow, an incident that is still under investigation.

4.2 Definition of risk scenarios including Exposure and Vulnerability analysis

Intended as a semi-quantitative representation of damage and losses that may occur in a specific context as a result of hazardous events (Simmons et al., 2017), a risk scenario is not limited to provide meteoric and hydrological descriptions but must also comprise and assessment of how given events can impact the downstream territory. Moreover, considering the indications provided by the main regulatory documents on the topic and in particular by the Civil Protection Document, risk scenarios must be based on the existing official documentation described in the first section of this paper. At present, these studies are rather outdated and therefore do not permit to account for the already tangible effects of climate change (manifesting in particular in the occurrence of very frequent and intense meteorological events) nor the territorial dynamics that have transformed the downstream areas over time. In fact, the "dam risk" depends not only on the delimitation of the potential flood wave downstream main variables (according to the arrival time, duration, maximum height and velocity) but also on the evaluation of the level of territorial exposure and vulnerability.

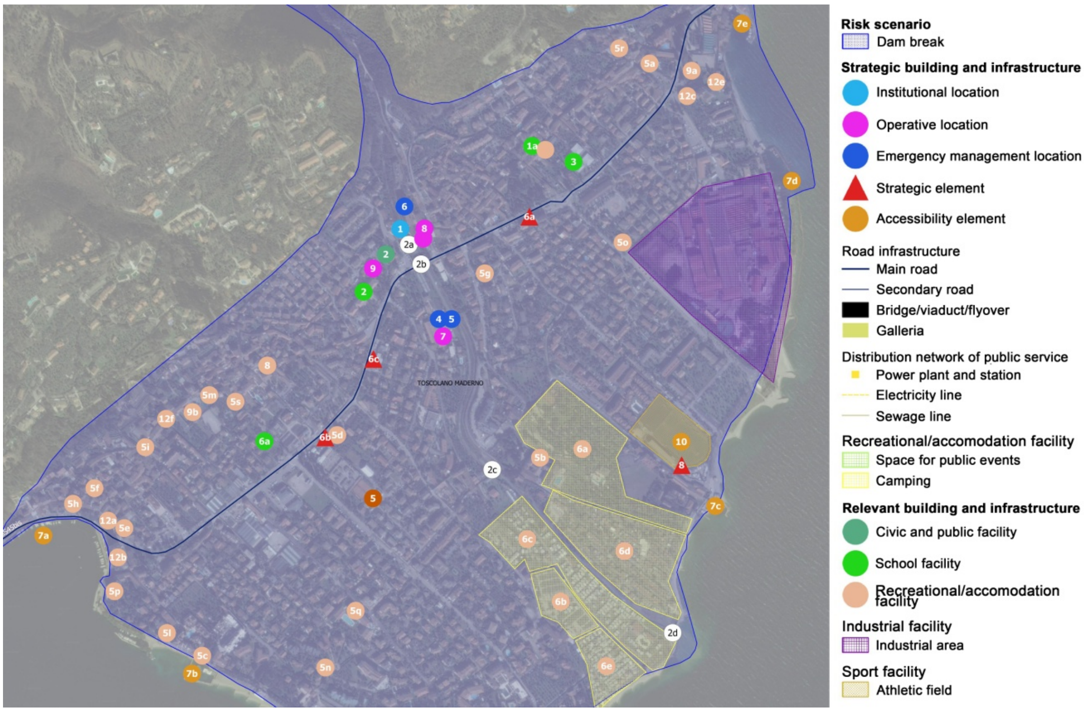


Fig.5 Mapping of strategic and relevant elements located in potentially flood area of Toscolano Maderno (BS) in case of Ponte Cola "dam break".

Human occupation (i.e. urban/rural settlements), public health (related with water supply, electricity, etc.), property (i.e. homes as well as industrial, commercial, touristy, agricultural and recreational facilities),

7 RASDA system - Database on Lombardia Region damage collection. Available at website: www.rasda.regione.lombardia.it/rasda/

transport infrastructures (i.e. roads, airports, railroads) and environmental resources are some of the elements that must be appraised. In this regard, the list of buildings and infrastructures approved by Lombardia Region (D.d.u.o. n. 7237 of 22 May 2019) lists all the assets to be considered - for civil protection purposes - strategic for their command, supervision and control function or relevant as public buildings susceptible to crowding or structures whose collapse may have serious consequences in terms of environmental, historical, artistic or cultural heritage. Moreover, in the evaluation of the human presence, specific conditions and the period and season of the year must be taken into account, since many areas downstream of dams have a tourist vocation and therefore it is possible to foresee a different presence of different population groups depending on when the hazardous event occurs.

For each exposed element, it is important to provide information not only on its geographical location (Fig.5) but also on the presence of any "features of Vulnerability" which may influence the propensity to physical damage of the element itself and/or of people who may be exposed at the time of the extreme event occurrence. In particular, the physical characteristics of the buildings/infrastructures (i.e. number of floors including underground floor, presence of temporary structures or barriers, etc.) and of particular categories of people in the urban function (i.e. disabled, elderly, etc.), the land use (i.e. commercial, productive, receptive), the possibility to have redundant functions and infrastructures must be taken into account to understand if and how the given urban system and its elements are able to cope with emergency conditions.

4.3 Operational response

On the basis of the defined risk scenarios, the operational response must be defined taking into due account the territorial perspective in emergency plans and coordinated with ordinary urban and land use planning.

In addition to the information provided by the Civil Protection Document for the definition of the intervention model (in particular about alert phases and communications flow), some actions can be better specified in the Emergency Plan and tailored to the territorial context, providing detailed indications regarding the different organisations and stakeholders involved, the establishment of new monitoring critical points (hydraulic and hydro-geological). Some indications have a direct impact on urban and land use planning, such as the need of an alternative road access to damaged areas; the need of an alternative location for emergency management facilities (both temporary and permanent) within the potentially floodable area; the implementation of an adequate population alert and warning system in “dam risk” areas. An important point that was raised in the discussion for the development of the Ponte Cola emergency plan related to the temporary use of the river for fishing and other recreational purposes during holidays, weekends and in the summer, requiring specific actions and alerting systems to be implemented.

Moreover, detailed indications should be given with regard to the identification of suitable areas for the deployment of rescuers equipment and vehicles needed to ensure an efficient intervention in the affected areas. Following field surveys such areas are selected on the basis of a set of criteria including: dimension (average size of about 25,000 m^2), location (in central position at provincial level but closed to the emergency planning area), type of pavement (paved or not), accessibility (closed to main roads system), availability of basic services. In such selection, coordination with local authorities that know the area and also the land ownership situation, is essential. Moreover, such areas cannot coincide with areas already identified in the Municipal Civil Protection Plan for safe staging of the evacuated population.

Last but not least, thematic maps are fundamental to describe the distribution of hazard levels, identify the perimeter of the areas affected by the flood wave in case of dam collapse and/or opening of the dam outlet works, the location of the strategic/relevant buildings and infrastructures, the location of the selected rescuers' and resources’ staging areas. Maps also provide support for decision making at an individual, family or community level, for the adoption of the most effective self-protection actions that can be consciously undertaken. It is not a matter of experiencing the presence of the dam as a potential and imminent risk, but of being aware of how it is managed in case of emergency conditions. As defined by Italian Civil Protection Code, citizens must be actively involved in risk prevention and civil protection exercises as opportunity to better know the specific procedures and actions.

4.4 Relationship with ordinary urban planning

There are several levels of needed integration between emergency and urban planning that nevertheless are still considered and administered as totally separated and independent documents. A first regulatory attempt to overcome such inconvenient separation is provided by article 18, point c of the National Legislative Decree 1/2018 setting the reform of civil protection in Italy. The decree leaves some room to interpretation, but what it clearly does is to require a stronger coordination between emergency and land use plans. In the following we attempt to provide some elements that should be considered as necessary steps for such stronger integration. The first and perhaps more obvious relates to the type of data, maps, and risk assessments on which both are grounded. In fact, emergency plans are broadly using scenarios, that is a number of deterministic hazard inputs occurring in a given area at different times of the year and day to account for differences mainly in exposure. Land use plan use have been broadly speaking mainly using probabilistic risk assessment as a reference, as the longer time horizon and the type of investment that is required makes it reasonable to account for probabilities of differential levels of severity of expected impacts. However, such clear cut distinction is not always satisfactory. If we look at what is the rule in the case of industrial risks and in particular regarding land use planning in the vicinity of hazardous installations according to article 13 of the Seveso Directive (2012/18/EU), different options have been taken by European countries, comprising a combination of approaches that privilege a scenario approach accounting for the differential likelihood of each potential occurrence whilst balancing the latter with the severity of damages.

Transferring this approach to emergency plans for natural hazards or combined man made (dams) and natural hazards (intense precipitation, landslides, slope instability), one needs to consider that if emergency plans are depicting a scenario as particularly devastating, the latter cannot be neglected in urban and land use plans, even when such scenario is evaluated as extremely rare. In fact, whilst envisaging the possibility of some kind of uses, for example temporary uses, particularly sensitive ones, such as critical infrastructures, schools, nursery schools or elderly facilities should be avoided. Therefore what can be suggested is that instead of a yes/no alternative, meaning any use or no use, urban and land use plans should discern among different types of uses, based on the understanding of the concentration and vulnerability of the population that is likely to use the space or the building in the area indicated as highly exposed in case of an incident to the dam. By the way such considerations may be well extended to any type of incident, combined or not, as was the case for the methodology to support a decision support system for planning developed in the EU funded Armonia project (Menoni, 2012). Certainly, what has to be harmonized in the future is the data foundation of both types of scenarios and probabilistic risk assessment especially when complete event scenarios that are including impacts on exposed territorial systems must be considered.

In the latter case, the geospatial data, maps, enumerated critical facilities should be common to emergency and land use plans to inform their design and updating. This is often not the case so that there is a misalignment between the two in terms of considered vulnerable and exposed elements and systems. More advanced information systems and more precisely interoperable and communicating databases should allow for overcoming such condition, permitting a mutual update and cross check of the continuous changes in the environment, both built and natural. Such systems are just starting to become operational in the administrations in charge of policies implying or impacting on territorial and spatial assets and systems, but in the near future they are likely to change the way the informational and knowledge base of public policies in different domains will be formed and maintained. In this regard, the Lombardia Region piloting experience must be mentioned in providing the Online Civil Protection Plans service as a dedicated information system to support urban planners, local professionals and technical office personnel in drafting and updating a civil protection plan. By coordinatiing activities among the involved Prefectures, Provinces and Municipalities, the Online service permits to share geospatial data and information not only about the level of hazard, exposure and vulnerability of a territory but also on the presence of strategic and relevant buildings and infrastructures or the identification of the gathering areas for rescuers and resources to be considered in case of crisis conditions.

Whilst the technological advances may depict a rather bright future, still there are crucial aspects to be discerned and further investigated. The first relate to spatial scale. In fact, datasets and maps that are available nowadays derive from data collection campaigns requiring different granularity and levels of detail, making it possible from a technical point of view to merge the information, but determining results of differing quality and requiring a rigorous description of the metadata behind. Spatial scale is also relevant when considering the level at which plans are developed and to guarantee their coordination. Both in emergency and urban planning there are plans developed at different scales.

Large scale emergency plans should in principle define regional scenarios, the deployment of regional or inter-agencies resources, whilst municipal plans identify specific locations for staging areas for the population, describe critical facilities that require attention. Nevertheless, local places may host strategic assets and infrastructures for the entire region, therefore the latter must be addressed also in regional plans. This type of interconnection has been constantly experienced in the regional emergency plan for dams discussed in this paper.

The latter are in fact key when several municipalities are involved in the same incident and therefore “cross-border” issues and necessities for mutual aid and support arise. In a rather similar vein, also land use and spatial plans are organised across different scales, apparently aiming at different purposes: at the larger scale more strategic considerations are pursued, whilst at the local level zoning and urban patterns are figured out. However, strategic infrastructures such as networks or even point shaped elements such as hospitals may well cross or lay within a neighbourhood, but clearly require a much broader understanding of their connection with other places and their role regionally or even nationally or internationally. Here again, information system can be of much help in providing the supporting layers needed for checking such interconnections, however the issue of the mutual regulatory regime and the level at which decisions are made must be still solved.

This rather annoying state of affairs requires that a different standpoint is taken, less concentrated on the multiplicity of different sectoral plans on the one hand and avoiding to require a total fully comprehensive documentation for each area, whilst focusing on the crucial risks (in our case) and opportunities (considering the entirety of interests and uses implied by a spatial or urban plan) that are specific to a given context, a given place, and researching the most relevant criticalities and solutions to problems that are in the meantime intersecting different “topics” and domains and specific to the area at stake.

Going back to the concept of scenario as a base of both land use and emergency plans, albeit considering in part distinctive features and differently prioritizing elements and assets, the temporal scale becomes very relevant as well. A time scale pertains to the phenomenon itself. As suggested by one of the speaker at the final seminar where the results of the joint effort between the Politecnico and the Lombardia Region teams were shared and discussed, the same return period considered for the design of safe dams is subject to changes. First, because of new legislation requiring for example a more cautious approach and that has shifted the requirement for safe dams shifting the return period probability for critical incidents from 500 to 1.000 years; second, because the way such probabilities and scenarios are estimated may be updated whenever better models or new knowledge becomes available; third because the phenomenon has changed for example as a result of climate change.

Such considerations are valid also when extending the evaluation to the full impact scenario, as exposure and vulnerabilities are subject to changes overtime and in some cases also rapidly and may vary depending on the time of the year or the hour when the event occurs. Very similar considerations can be held true also for scenarios that are used for spatial and land use planning purposes in accordance for example with article 6 of the Floods Directive (2007/60/CE). One in fact should not only focus on the changes in the physical phenomenon but also on how the use of the territory, permanent and temporary, the use of buildings and their parts by different populations (for example with an increase in allowing basements' occupancy by dwellers) has changed vulnerability and exposure to natural extremes. Finally, there is the issue of how to update scenarios whenever new circumstances or a recent disaster has occurred. In this respect there is the need to complement planning with data that is generated after the event and sheds new light on unforeseen exposure, vulnerability or hazards features that had been underestimated or not properly addressed in previous risk assessments.

The need to use post disaster damage data has been increasingly called for in recent activities at the European Commission level (see Marin Ferrer et al., 2018; Menoni et al., 2017; Walia and Menoni, 2020). However, in order to inform risk assessments and scenarios such activity must become part of an ordinary procedure and carried out according to a certain level of standardization. Elsewhere (Menoni, 2018) we have suggested that adaptive planning seems a recommendable solution in order to uptake new evidence and new information that becomes available at certain turning points (such as a disaster that has occurred in the area). In an article dated 2005, Couclelis argued that adaptive planning must be considered a defeat of strategic planning and thinking, giving up providing a vision for the future of an area whilst trying to accommodate for incremental changes. The Author was referring though to scenarios of future land and territorial configurations as derived from models articulating a number of alternative economic, social and geographic pathways. However, here we wish to respond to the reasonable critique with the following two arguments. First the type of future scenarios that Couclelis (2005) had in mind do not or only marginally include significant changes in the environment, that instead seem to be relevant especially in the light of current large environmental changes we are facing at different spatial scales; second we would like to suggest that adaptation by means of including new information and knowledge whenever it becomes available my well re-direct a more strategic vision, providing actually the possibility to monitor to what extent the territorial system is going towards the "wished" type of development. In this regard, whilst continuing to consider large disasters as turning exceptional points, emergency plans can still be the basis on which the knowledge, experience and understanding of the environment and the territorial setting of a large number of stakeholders, albeit not ordinarily considered as being part of the "urban and land use planning community", can be taken on board, highlighting criticalities and changes that are generally neither perceived nor tackled by ordinary spatial and urban plans.

Instead, in a more integrated process, envisaged changes in land uses and in urban functions and configurations can inform and direct the attention of emergency planners and risk managers towards emerging threats and vulnerabilities, whilst on the other side, emergency preparedness may inform variants or recent additional documents to cities and regional plans, such as climate adaptation strategies or resilience plans.

5. Conclusion

The experience reported in this paper is the result of a joint collaboration between researchers in engineering and land use planning and the Department of Civil Protection of the Lombardia Region. It describes the challenges and the solutions to a rather complex work necessary to develop an emergency plan for dams that provide sufficient consideration for the complexities in terms of vulnerability and exposure of communities and assets downstream. The legislative framework that governs the development and the expected outputs of such plans at the regional level are described and compared to other countries. The proposed methodological approach and the model plan are described in detail and some examples are provided on how territorial aspects have been appraised and integrated in the envisaged response mechanism.

Both achievements and challenges have been associated to this effort. As for the former, certainly a significant added value is embedded in the systemic approach that has been taken linking the hazard factors to the exposure and vulnerability of infrastructures, the built environment and communities living downstream. The territorial context has entered in all considerations regarding the potential impact in the form of full damage scenario and the logistics of the foreseen response. Different data layers have been used taking advantage of the rather rich and well developed GIS open system of the Lombardia Region. Integrated data and contributions have been achieved thanks to a cooperative approach between different levels of governments and with interested parties and stakeholders not without some frictions due to competing land uses and to the need to balance energy production with safety. In this regard, the construction of a digital platform can be useful for knowledge management and territorial organization of the emergency in a resilient perspective (Di Lodovico and Di Ludovico, 2018) with the integration of plans identifying - at different levels – information and actions to be considered by all the stakeholders involved in the territorial management (before, during and after) of flooding events caused by water releases, planned or unplanned.

Challenges and criticalities have been encountered too, mainly related to the difficulty in convincing administrations of the need to take a dynamic multirisk approach, considering in the meantime the potentiality for simultaneous hazards occurring and triggering one another and the dynamic evolution of urban settlements both requiring a frequent update and reconsideration of scenarios. As the latter are approved in official settings it is then difficult to change, update or reassess them even in the face of evident need to do so as many years have passed since the undertaking of the studies on the basis of which scenarios have been produced. Also, multirisk approaches are difficult and require a deep understanding of multiple phenomena and the limitations of models available to tackle them, though they lead to a condition in which it is not always easy to determine what has been the exact trigger of damage in a given event. Furthermore, multiple hazards as well as multirisk situations require by definition cross-scale analyses that develop from local to regional and from regional to local to account for different types of phenomena entailing different spatial levels and to systemic vulnerabilities due to complex interconnections between infrastructural, economic and social systems. This challenge the current structure of public administrations and government in general as correctly suggested by Handmer (1999): segments of decisions and resources are managed in silos with few interaction and cooperation activities that are most of the time carried out by individuals but not rewarded adequately at the institutional level. A different approach is clearly needed to manage complex hazards (composite, such as those related to the presence of a large dam) in complex settings, morphologically, environmentally as well as for the existing infrastructures, social and economic drivers. Such an approach should stem from the acknowledgment that complex risk situations and multi-level plans of different types call for shared responsibilities including more participatory approaches involving local communities and an extended risk governance (May and Williams, 1986).

Finally, some considerations have been developed on the necessary relations between urban, spatial and land use plans on the one hand and emergency plans on the other. Partly different stakeholders are involved, and also different timescale: the horizon of the latter is much shorter than that of the former type of plans. Still significant advantages can be obtained using common datasets, maps and risk assessments. Considering the time scale, urban planners should become more familiar with the idea that landscapes, especially in mountain areas where many large dams are located, may be very dynamic and sometimes change even dramatically in a matter of few hours. In our visit to the Pagnona dam the dramatic transformations produced by each intense precipitation episode was under our eyes and clearly defeated the many attempts and projects already in place to manage properly the infrastructure. In the light of such dynamics implying different temporalities, emergency and land use planners can get significant advantage working more closely together and constructing jointly full event scenarios the consistency of which can be measured and monitored overtime and which can provide a basis for different types of projects aimed at the safety and the well being of communities living downstream large dams.

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Assessing the potential of green infrastructure to mitigate hydro-geological hazard

Evidence-based policy suggestions from a Sardinian study area

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Abstract
This study focuses on the relations between the definition and implementation of a green infrastructure (GI) and hydro-geological hazard. GIs are spatial structures supplying a wide range of ecosystem services, here related to the following: nature, natural resources and biodiversity conservation; landscape and recreation; agricultural and forestry production; local climate regulation; climate change impact mitigation through capture and storage of carbon dioxide. A methodological framework is defined to assess the relations between GI and hydro-geological hazard through inferential analysis based on dichotomous-choice Logit models, under the assumption that the implementation of GI within planning policies could enhance environmental protection and people's wellbeing. By applying the methodology to a coastal study area in Sardinia (Italy), this study shows that landslides are more likely to occur in areas showing high natural values and high carbon dioxide capture and storage capacity, whereas productive agro-forestry areas are comparatively more likely to feature severe floods, and areas with significant landscape assets and recreation potential are associated with low flood and landslide hazard. On these bases, a better understanding of the role that could be played by GI as regards hydro-geological hazard is gained, and policy recommendations aimed at mitigating the associated risks are identified.

Keywords
Environmental hazard; Green infrastructure; Ecosystem services; Logit models.

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1. Introduction

Climate change negatively impacts on the hydrological cycle of the Earth and on phenomena connected with water management. Hydrogeological instability is conceptualized as a change of the natural flow of water on, above and below the surface of the Earth due to its interaction with the anthropized spatial system (Margottini, 2015). Therefore, hydrogeological instability represents a hazard to local population, infrastructures, and economic and productive systems (Trigila et al., 2018). For example, in 2018 in Italy 7,275 municipalities (91% of the Italian ones) were found to be exposed to landslide and/or flooding hazards. Moreover, 16% of the national territory is classified as high-hazard area, and 1.28 million people live in areas featured by landslide hazard and more than 6 million in flooding hazard areas (Trigila et al., 2018; Di Giovanni, 2016).

Typical consequences of hydrological phenomena are landslides, flooding, coastal erosion, subsidence, and avalanche.

According to Cruden & Varnes (1996), "The term 'landslide' describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these. The materials may move by falling, toppling, sliding, spreading, or flowing" (p. 36). The increase in rapid development, deforestation and urbanization results in higher probabilities of landslide events (Tiranti & Cremonini, 2019). Moreover, although several authors studied the impacts of climate change on landslide occurrence and magnitude through the use of model projections (Seneviratne et al., 2012; Stoffel et al., 2014), the influence of climate change on stability of slopes is still a matter of debate (Gariano & Guzzetti, 2016).

According to the European Union Directive 2007/60/EC on the management of flood risk, flood means "the temporary covering by water of land not normally covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems" (art. 2, paragraph 1). Flood events are affected by sea level raise, heavy rainfalls, impervious surfaces, and ageing drainage infrastructures (Chen et al., 2019).

Although for a long time gray infrastructure has represented the only operational tool to address landslide and flooding hazard and related environmental damages (Badiu et al., 2019), more recently the implementation of nature-based solutions has revealed very effective in mitigating the impacts of such disasters (Caparrós-Martínez et al., 2020). Therefore, the use of green infrastructure (GI) has gained increasing importance within the international debate. Caparrós-Martínez et al. (2020) argue that, even though the technical functions of GI are connected to the management of the integrated water cycle, GI should be mainly identified in relation to three issues: smart growth, climate change adaptation, and social health and wellbeing. According to the US-EPA (United States Environmental Protection Agency, 2017) "Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits. While single-purpose gray stormwater infrastructure - conventional piped drainage and water treatment systems - is designed to move urban stormwater away from the built environment, green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits." In other words, the US-EPA identifies GI as a provider of mitigation of landslide and flooding impacts, since GI is engineered to intercept rainfalls, increase the availability of permeable surfaces and soil water storage, and delay and decrease the intensity of peak flows (Bartens and Mersey Forest Team, 2009). For instance, large trees may potentially absorb 80% of precipitation, whereas little trees absorption is around 16% (Xiao & McPherson, 2002).

Caparrós-Martínez et al. (2020) identify three types of benefits, i.e. economic cost savings, multifunctional character and lower environmental cost, and ability to adapt to different territorial scales. In their view, GI includes healthy ecosystems that help to restore and reestablish spatial connections between damaged habitats and, in general, between natural and semi-natural areas, in contrast to gray infrastructure that requires continuous adaptations to social and economic factors, such as population growth (European

Commission, 2013a). Furthermore, GI entails benefits such as water purification generated by natural wetlands, conservation and enhancement of biodiversity, and carbon capture and storage, while gray infrastructure, such as a treatment plants, are single-purposed, in that they only aim at purifying wastewater (European Commission, 2013a; 2013c). Finally, GI may be adapted to different scales, ranging from the regional to the urban level (Caparrós-Martínez et al., 2020).

Moreover, several studies (Lai & Zoppi, 2017; Lai et al., 2017a; 2018; Liquete et al., 2015; Ronchi et al., 2020) highlight that GI may represent a tool to mitigate land-taking processes. In particular, Lai & Zoppi (2017) analyze how the provision of Natura 2000 sites, regarded by the EU as core areas within GI, affect land-taking processes. The results of this study put in evidence that the presence of natural and semi-natural areas, such as Natura 2000 sites, is negatively correlated to land-taking processes. Land cover transitions from natural and semi-natural areas to artificial areas due to urbanization, agricultural expansion and abandonment, and deforestation, entail habitat fragmentation and degradation and, as a consequence, biodiversity loss (Calvache et al., 2016). GI as a network of natural and semi-natural areas reduces habitat fragmentation, and, that being so, policies aimed at increasing natural and semi-natural areas are strategically relevant to mitigate land-taking processes (Lai et al., 2017b).

The relation between GI and hydrological instability is a matter of study in recent literature (Zucaro & Morosini, 2018). Mei et al. (2018) investigate the role of GI in mitigating flood events through the storm water management model (SWMM) and life cycle cost analysis (LCCA), in order to support planning and decision-making processes. Chen et al. (2019) assess the effectiveness of the implementation of practices based on GI on water supply and quality. Papathoma-Koehle & Glade (2013) analyze how changes in vegetation and land cover influence landslide events in terms of occurrences, consequences, and implications.

Although the implementation of GI based on natural and semi-natural areas is quite effective to mitigate the negative impacts of landslides and floods, its use is still limited due to the difficulty to project and forecast economic impacts and feasibility (Caparrós-Martínez et al., 2020, European Commission, 2013b). Indeed, the assessment of GI-related planning policies is generally based on counterfactual methodologies which imply the availability of huge databases and complex economic approaches which are often too expensive in terms of financial resources and time needed to obtain reliable outcomes (Palmer at al., 2015).

The assessment of the effectiveness of GI practices on hydrological events is therefore an important issue in the current literature; however, available studies mainly focus on specific GI practices, such as green roofs, permeable pavements, bioretention cells, rain barrels, and vegetated swales (Palla & Gnecco, 2015; Liu et al., 2014). This article aims at defining a methodological approach to investigate the relations between a regional GI (RGI) and hydrogeological hazards, identified by landslides and floods, by combining GIS-based analysis with regression models in order to define strategies and policies to mitigate the potential negative environmental impacts generated by such hazards. The methodological approach is implemented into a coastal area of Eastern Sardinia, Italy.

The article is structured into five sections as follows. The second section describes the study area, shows how the dataset is built, and discusses the methodological approach, which combines a GIS-based spatial analysis with a regression model. The third section presents the results derived from the implementation of the methodological approach in relation to the study area. The results are discussed in the fourth section, while the fifth section defines the implications of the study in terms of planning policy recommendations, discusses limitations and identifies future research perspectives.

2. Materials and Methods

This section is organized as follows. In the first subsection the study area is described within the regional spatial context of Sardinia. Next, the discrete-choice Logit model estimated to detect the relations between

RGI and environmental hazard is defined and discussed. In the last subsection, the data which operationalize the model are presented.

2.1 Study area

The area chosen for this study lies on the eastern side of Sardinia, one of the main islands in the Mediterranean Sea (Fig.1). With a size of approximately 24,000 km^2 and a population of 1,611,621 inhabitants[1], Sardinia has a very low residential density of around 67 inhabitants/km^2, mostly concentrated in coastal zones and peaking in the main urban areas. To the contrary, inner areas are sparsely populated and present worrying trends of steady depopulation, to which the persistent low levels of infrastructure and services greatly contribute. The climate of the island is typically Mediterranean, and the landscape is mostly hilly and rugged, with only a few plains that are significant for agriculture. Close to the coastline, several small valleys can be found in correspondence with rivers' estuaries and coastal wetlands, and in these valleys recent coastal urbanization, often connected to the tourism sector, has replaced traditional agricultural and grazing uses.

Bordering the Tyrrhenian Sea to the East, the study area chosen for this study stretches over 1,306.12 km^2, roughly amounting to one twentieth of the whole island. As shown in Fig. 1 (panel "C"), fourteen coastal municipalities are fully comprised within the study area, with a fifteenth one (Gairo) only included as far as its coastal area is concerned; the latter is an enclave completely separated from the rest of the inland municipal territory to which it belongs, and enclosed between the sea and the two municipalities of Cardedu and Tertenia. The morphology is quite hilly and rugged in the central part of the study area (i.e. the Gulf of Orosei), characterized by limestones and dolomites, and hosting canyons, steep cliffs and pocket beaches (Arisci et al. 2000; Cossu et al., 2007). The northern and southern parts, still hilly but with gentler slopes, host large sandy beaches (such as, for instance, Orrì in Tortolì to the south, or La Cinta in San Teodoro to the north: Batzella et al. 2011), as well as rivers of significance in the regional context and their alluvial plains (for instance, Rio Quirra in Tertenia, Rio Cedrino in Orosei, and Rio Posada in the namesake municipality), lagoons and wetlands (for instance, in Tortolì, Orosei, and San Teodoro).

As in all of Sardinia, the climate in the study area is Mediterranean: winters are mild and moderately rainy, while summers are hot and dry. Concerning physiography, approximately 60% of the study area belongs to the thermo-Mediterranean zone and the remainder to the meso-Mediterranean zone, as per the map developed by Canu et al. (2015). Vegetation series are closely linked to physiography, and the study by Bacchetta et al. (2009) shows that nearly all the study area hosts species belonging to either the Sardinian thermo-meso-Mediterranean series or the Sardinian thermo-Mediterranean series, as follows: approximately 53% is taken by the holm oak tree series, 20% by the cork tree series, 12% by the wild olive tree series, and 6% by the *Juniperus turbinata* series; finally, negligible percentages of several other vegetation series concern the rest of the study area.

Hydrogeological hazard has historically been significant in the study area, hence its significance for this study. As for floods, extreme events in recent history took place in this part of the island in 1951, 2004, 2013 (Bodini & Cossu, 2010; Cossu et al., 2007; De Waele et al., 2008; Righini et al., 2017). As far as landslides are concerned, approximately 175 events occurred up to 2007 have been recorded by the Italian landslide inventory (IFFI) project2 in the study area. Such events are mainly clustered in the central and south-most parts of the study area; the former includes the municipalities of Baunei, Dorgali and Orosei, where fall and

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1 Data from the National Census as of January 1st, 2020: http://dati.istat.it/

2 IFFI is the acronym of "Inventario dei Fenomeni Franosi in Italia", which can literally be translated as "Inventory of Landslide Events in Italy". For the Sardinian region, the full IFFI 2007 dataset can be retrieved from https://idrogeo.isprambiente.it/app/page/open-data. Moreover, a larger spatial dataset, which includes also more recent observations and provides additional information such as event date and pictures, can be visualized from https://idrogeo.isprambiente.it/app/iffi/r/20.

topple types3 prevail (Cinus et al., 2007), while in the latter, only concerning the municipality of Tertenia, topples prevail, although some translational slides have also occurred (Cinus et al., 2007).

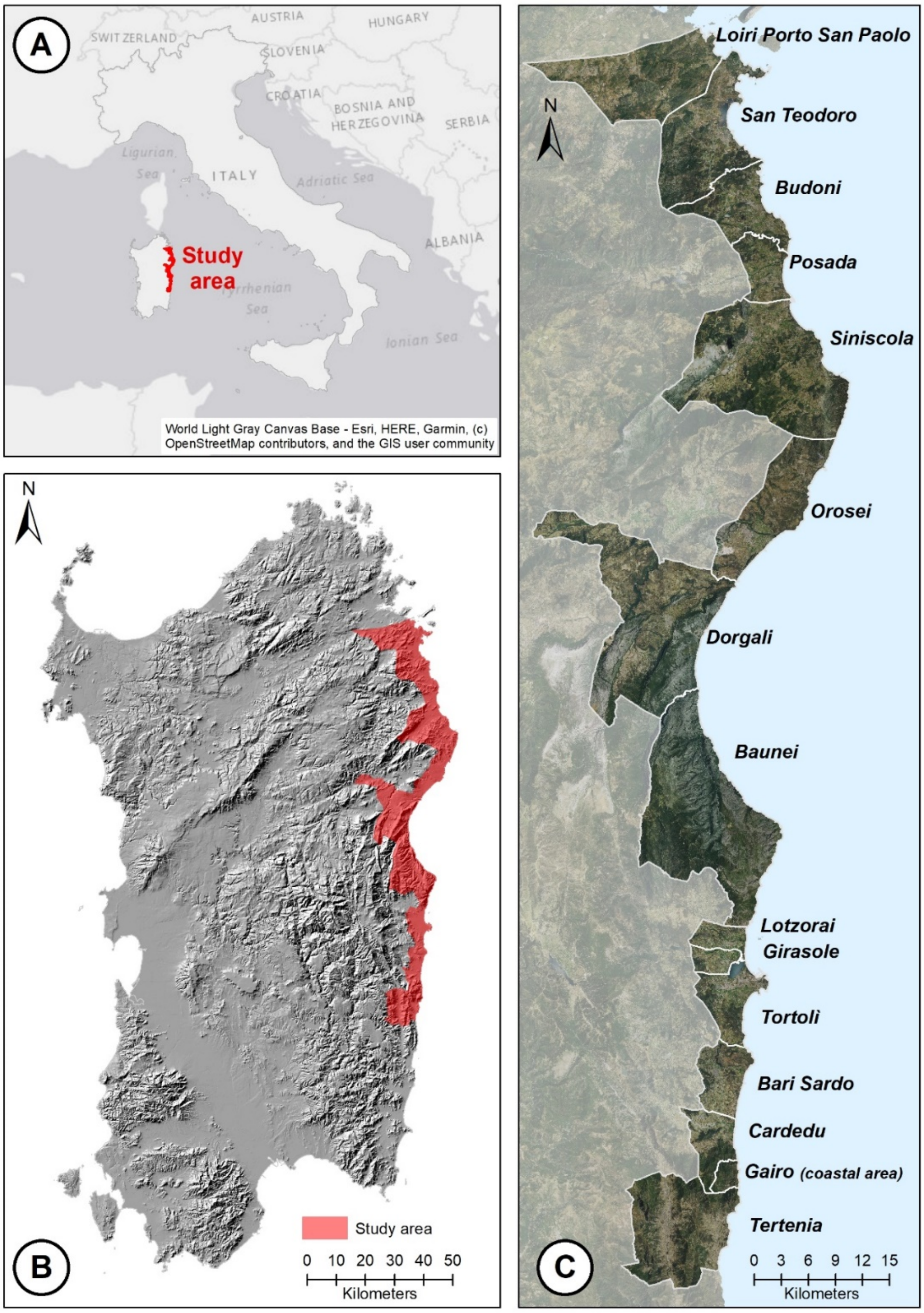

Fig.1 Location of the study area within Italy (A) and Sardinia (B), and municipalities included therein (C).

Finally, as for urbanization, Tab. 1 provides data on population and land take in the study area. As per the definition by the European Environment Agency (2019), land take is here understood as the "change in the area of agricultural, forest and other semi-natural land taken for urban and other artificial land development", which, in Italy, is monitored on an annual basis by the National Institute for the Protection of the Environment (original Italian: ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale). Data from the latest available report (Munafò, 2020) show that, if all of the 15 municipalities in the study area are taken into account, then land take is higher than that of the whole island, both in terms of quantity of land taken per

3 For the full taxonomy of landslide types the reader can refer to Varnes (1978) and to Crudern & Varnes (1996).

unit of area, and in terms of land taken per capita (Tab. 1, penultimate and last column respectively). However, a closer look at Tab. 1 unveils a very uneven situation across municipalities in the study area, as land take as percentage of the "consumed soil" per unit of area ranges between 0.78% (Baunei) and 13.08% (Tortolì). However, such figures are highly dependent on the size of the municipal area. Hence, the unbalanced distribution of land take across the 15 municipalities is more significant if the share of "consumed soil" per capita is considered. What is quite evident, here, is that in well-renowned coastal tourist destinations, such as Budoni, San Teodoro, or Loiri Porto San Paolo, land take per unit of resident population is approximately (or even higher than) twice as much as the regional figure, which exposes the impact of tourism and related infrastructure on urbanization in coastal areas.

Municipality	Area [km^2]	Population (*)	Population density [residents/km^2]	Land take [%] (**)	Land take [m^2/inhabitant]
Bari Sardo	37.43	3,908	104.40	5.97	572.20
Baunei	212.08	3,549	16.73	0.78	465.49
Budoni	56.17	5,191	92.40	8.74	945.69
Cardedu	32.35	1,953	60.36	4.32	715.93
Dorgali	224.82	8,502	37.82	2.51	662.83
Gairo (***)	78.32	1,365	17.43	1.79	1027.63
Girasole	13.23	1,320	99.77	6.73	674.59
Loiri Porto San Paolo	118.43	3,604	30.43	3.32	1090.79
Lotzorai	16.51	2,115	127.59	7.23	566.29
Orosei	90.55	6,928	76.51	6.33	826.93
Posada	33.07	3,041	91.97	6.56	713.18
San Teodoro	104.76	4,978	47.48	5.34	1124.93
Siniscola	199.87	11,509	57.57	3.86	670.20
Tertenia	117.76	3,883	32.97	2.12	642.77
Tortolì	40.47	10,769	266.11	13.09	492.01
Total 15 municipalities	1375.82	72,615	52.77	3.79	718.94
Sardinia	24,090	1,611,621	66.90	3.28	490.28

(*) As of January 1st, 2020. Source: National Census (http://dati.istat.it/).
(**) As of 2019. Source: Munafò, 2020. Defined as "Consumed soil" in the supplementary materials (http://groupware.sinanet.isprambiente.it/uso-copertura-e-consumo-di-suolo/library/consumo-di-suolo/indicatori/).
(***) Data in this table refer to the whole municipality, but in this study only the coastal area (8.62 km^2) is included; data on population and land take are not available for Gairo's coastal enclave only.

Tab. 1 Municipalities in the study area: size, population, population density, and land take.

2.2 Methodological framework

Multiple or dichotomous choice models (DCMs) analyze phenomena characterized by multiple or dichotomous nominal alternatives. These models were originally formalized and applied by McFadden (1978; 1980) in order to characterize behavioral choices of consumers. McFadden (1978; 1980; 2000) built on William's work (1977) through the implementation of choice models related to agents' behavior on the basis of standard microeconomic theory. These models integrate sets of agents' features as covariates, whose alphanumerical values may or may not be part of the available information; were they not available, they would be integrated into the model as random characteristics. A number of studies are points of reference to formalize multiple or DCMs (Ben-Akiva & Lerman 1985; Ortúzar & Willumsen 2001; Train 2009), which assume imperfection of agents' rationality and information incompleteness (Tversky 1972).

In this article, DCMs are used because the variables which identify flood and landslide hazards are dichotomous, since both flood hazard and landslide hazard can be classified into the "relevant" and "weak" categories, by grouping the hazard classes of the Sardinian region as follows: in case of flood hazard, "presence of flow hazard" into the former and "no hazard" into the latter; in case of landslide hazard, "very high," "high" or "medium" hazard into the former, and moderate or no hazard into the latter.

Building on Nerlove & Press' (1973), Greene's (1993), and Zoppi & Lai's (2013), this study implements a Logit DCM. Logit models (LMs) associate a logistic probability distribution to the two events that characterize the phenomenon at stake.

The model considers a set of two events {0,1}, with probability of event "1" and "0" given by, respectively:

$$\text{Prob}\ (1) = \frac{e^{\beta_1^{'} \mathrm{x}_1}}{1+\sum_{k=0}^{1} e^{\beta_{\mathrm{k}}^{'} \mathrm{x}_{\mathrm{k}}}} \tag{1}$$

$$\text{Prob}\ (0) = \frac{1}{1+\sum_{k=0}^{1} e^{\beta_{\mathrm{k}}^{'} \mathrm{x}_{\mathrm{k}}}} \qquad (2)^{4}$$

where β is a vector of coefficients and x is a vector of characteristics related to the event k, k ∈ {0,1}. As per Greene (1993, p. 666, see footnote 3), a unique non-zero vector β_1 can be identified, and, as a consequence, a unique vector of coefficients β, i.e. vector β_1 of formula (1), is estimated by solving the maximization problem of the following log-likelihood function, ln L, in the vector of coefficients β:

$$\ln L = \sum_{i=1}^{M} \sum_{k=0}^{1} d_{ik} \ln Prob\ (k) \tag{3}$$

where M is the total number of observations, and d_{ik}=1 if in the i-th observations the event k occurs, and d_{ik}=0 otherwise. The vector of coefficients β is implemented into (3) through formulas (1) and (2), where the Prob(k)'s are expressed as functions of vector β through formulas (1) and (2).

The maximization of the likelihood function ln L is identified by a system of N+1 equations in the N+1 coefficients of vector β. Each equation takes the following form:

$$\frac{\partial \ln L}{\partial \beta_j} = \sum_{i=1}^{M} [d_{ik} - \ Prob\ (k_i)] x_{ij} = 0 \tag{4}$$

where β_j is the j-th coefficients of vector β, x_{ij} is the i-th observation concerning characteristic j of vector x, k_i is the event associated to the i-th observation, such that k_i ∈ {0,1}, and j ∈ {0,N} is the number of components of vectors β and x.

The values of the vector of coefficients β which solve the maximization problem (4) make it possible to calculate the marginal effects of a change of the value of a characteristic x_i of vector x on the probability that the event k occurs, $\frac{\partial Prob\ (k)}{\partial x_i}$, as follows:

$$\frac{\partial Prob\ (k)}{\partial x_i} = [Prob\ (k)]\{\beta_i - \sum_{j=0}^{N} [Prob\ (k)]\ \beta_j\} \tag{5}$$

The model's estimates make it possible to derive the marginal effects of formula (5), for instance as regards the x_i's mean values, and the probabilities of the events k's. Furthermore, the model makes it possible to derive the standard errors of the components of vector β and of the marginal effects of formula (5).

A further assumption is that the random distribution of the event k, k ∈ {0,1}, is such that observations are independent from each other, which entails that the observations concerning the explanatory variables are unrelated to each other, and deterministically identified by the available data. As a consequence, the random element of the distribution of event k, ε, is featured as follows (Cherchi, 2012; Cannas & Zoppi, 2017):

- E(ε|x) = 0, i.e., the expected value of the random term conditional on the values of vector x equals zero; x is the set of explanatory variables;

[4] If $\beta_j^* = \beta_j + q$ for any nonzero vector q, the identical set of probabilities result, as the terms involving q all drop out. A convenient normalization that solves the problem is to assume vector $\beta_0 = 0$. The probability for Y = 0 is therefore given by (2) (Greene, 1993, p. 666).

- Var(ε) = σ^2, i.e., the variance of the random term is constant;
- $E[\varepsilon_i \varepsilon_j|X] = 0$, there is no correlation between the random terms of the observations, which entails that the covariance equals zero; X is the set of observations concerning vector x.

Model (1) through (5) operationalizes as follows.

Two models are estimated, where the dependent dichotomous variables are, respectively, flood hazard and landslide hazard. These variables correspond to the k's events in model (1) through (5), k ∈ {0,1}.

Variable	Definition	Mean	St.dev.
FH	Flood hazard - dichotomous variable: • 1 if any level of flood hazard but no hazard is detected; • 0 if no hazard is detected	0.090	0.286
LH	Landslide hazard - dichotomous variable: • 1 if the level of flood hazard is "very high," "high" or "medium"; • 0 if eitherthe level of landslide hazard is moderate or no hazard is detected	0.448	0.497
Natval	Natural value. Continuous variable in the interval [0,1]. Potential capability of biodiversity to supply final ecosystem services in face of threats and pressures it is subject to. The value was calculated using the software "InVEST"[5], tool "Habitat quality". Data inputs for the model were: • land cover types as per the 2008 Regional land cover map (rasterized); • raster maps of ten spatial threats listed in the standard data forms for Natura 2000 sites. The ten selected threats are as follows: cultivation; grazing; removal of forest undergrowth; salt works; paths, tracks, and cycling tracks; roads and motorways; airports; urbanized areas; discharges; fire and fire suppression; • weights and decay distance for each threat from expert judgments; • sensitivity of each land cover type to each threat from expert judgments; • accessibility to sources of degradation, in terms of relative protection to habitats provided by legal institutions. The three categories we used are as follows: natural parks, areas protected and managed by the regional Forestry Agency, Natura 2000 sites	0.844	0.269
Consval	Conservation value. Continuous variable in the interval [0,1]. Presence of natural habitat types of Community interest (as listed in Annex I of the Habitats Directive) and conservation importance thereof. Consval=0 for areas where no habitats of Community interest have been identified; else Consval=P*(R+T+K) [normalized in the interval [0,1] where: • priority habitats P=1.5 in case of priority habitat, P=1 in case of non-priority habitat; • rarity R= [1,5] depending on the number of Natura 2000 standard data forms in which the habitat is listed within the regional Natura 2000 network; the higher the number of occurrences, the lower the value of R; • threats T= [1,5] depending on the number of threats recorded in the standard data forms for the Natura 2000 sites in our study area; the higher the number of threats, the higher the value of T; • knowledge K=[1,4] depending on the level of current knowledge (e.g. number of onsite surveys, existence of up-to-date and reliable monitoring data) of a given habitat within the regional Natura 2000 network; the lower the knowledge, the higher the value of K	0.148	0.195
Landsval	Landscape value. Discrete variable in the interval [0,1] accounting for whether, and to what extent, a given parcel of land is protected under the 2006 Regional Landscape Plan either as "Environmental landscape asset" or as "Cultural-historic landscape asset". For each protection level defined in the Regional Landscape Plan, a score was assigned in the [0,1] interval depending on the level of restriction. In case of overlapping protection levels, the maximum score was assigned to the parcel	0.521	0.497
Recrval	Recreation value. Continuous variable in the interval [0,1]. Recreational attractiveness of landscapes and natural habitats. The average photo-user-days per year between 2010 and 2014 was calculated using the software "InVEST" (tool "Recreation") and a 3-km grid, and subsequently normalized in the interval [0,1]	0.006	0.027
Agrofor	Agroforestry value. In the absence of comprehensive spatial data on agricultural and forestry productivity, estimated value of rural plots (k€/ha) as of 2017 was used as a proxy	3.601	4.029
LST	Land surface temperature detected in August 2019 (K)	311.174	3.554
CO2Stor	Carbon dioxide storage per unit of area (Mg/(100 m^2))	1.098	0.350
Altitud	Elevation (m)	234.084	226.531
Slope	Slope. The inclination of slope is provided as percent rise, also referred to as percent slope. The values range from 0 to essentially infinity. A flat surface is 0% and a 45-degree surface is 100%, and as the surface becomes more vertical, the percent rise becomes increasingly larger.[6]	23.009	21.501

Tab. 2 Definition of variables and descriptive statistics

[5] InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a free software program developed by the Natural Capital Project and available from http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/index.html [accessed 4 November 2020].

[6] https://desktop.arcgis.com/en/arcmap/10.7/tools/spatial-analyst-toolbox/slope.htm [accessed 4 November 2020]

The characteristics which are the components of vector x = (1, x_1, …, x_N) and their descriptive statistics are reported in Tab. 2. The occurrences of the k's events are conditional upon the X_i's characteristics, according to a logistic distribution estimated through the identification of the coefficients which are the components of vector β, by implementing model (1) through (5). The characteristics are the following: natural value, conservation value, landscape value, recreational value, agroforestry value, land surface temperature and carbon dioxide capture and storage capacity. Moreover, altitude and slope are used as control variables.
These characteristics are described and discussed in the following subsection.

2.3 Data

Flood hazard and landslide hazard in Italy are mapped at the sub-national level, within a sectoral planning tool termed PAI (an acronym for "Piano di Assetto Idrogeologico", verbatim "Hydrogeological Setting Plan"), with which municipal land use plans and their zoning schemes must conform. Notwithstanding several disasters occurred in the XX century, such as Polesine in 1951, Vajont in 1963, or Florence in 1966, it was only in 1989 that the first law (no. 183/1989) making provisions for basin management was passed. Such law made it compulsory to approve watershed management plans that were conceived of as knowledge-providing tools, as well as planning tools that ought to identify technical interventions to reduce hydrogeological risks and impacts on human activities and set up a financial program to be revised every three years. Because of the comprehensive character of such plans, the implementation process was extremely slow (Scolobig et al., 2014). Therefore, when the Sarno debris flow disaster occurred in 1998, a new law (no. 267/1998) was quickly passed to speed up these planning processes and ensure that each River Basin Authority approved at least a "smaller" plan, the PAI. Albeit still part of the comprehensive watershed management plan, PAI's focus only on hydrogeological risk and include assessment and mapping of flood and landslide risks, hence also assessment and mapping of flood and landslide hazards, as well as of vulnerable areas, buildings and infrastructure[7].
Because the island of Sardinia is identified as a macro-basin, a single watershed management plan and its PAI concern the whole region. The Sardinian PAI, first approved in 2004, in its initial version mapped hydrogeological risk and hazard only within specific parts of the island, such as, for instance, those in which severe landslides were known to have taken place in history, or those in which so-called "critic river segments" were identifies through hydraulic models (RAS, 2000). Hazard classes within the PAI range in the 0-4 interval, as per Tab. 3.

Hazard level	FH level definition	LH level definition
0	Absent (not even mapped)	Absent
1	Low (return period: 500 years)	Moderate
2	Moderate (return period: 200 years)	Medium
3	High (return period: 100 years)	High
4	Very high (return period: 50 years)	Very high

Tab. 3 Flood and landslide hazard classes as per the Sardinian PAI (RAS, 2004, pp. 23-25).

Since 2004, both flood and landslide hazard and risk maps in the Sardinian PAI have continuously been updated through two main mechanisms: first, studies commissioned by the regional administration; second, studies commissioned by municipal administrations, usually as part of their land-use making processes, because updated flood and landslide assessments concerning the whole municipal territory are prerequisite for the approval of land-use plans. Municipal assessments make use of the same hazard levels as the PAI, i.e. those

7 Within the Sardinian PAI, the traditional disaster risk equation is used: R=H*V, where R=risk, H=hazard, V=vulnerability.

listed in Tab. 3, and of the same methodologies as the River Basin Authority, which means that the outcomes of the regional and municipal assessments are comparable. Despite being thoroughly examined and approved by the River Basin Authority, not all the assessments and maps commissioned by the municipalities call for a revision of the PAI; in other words, it is up to the River Basin Authority to decide when the maps commissioned and produced at the municipal level are to be integrated within a new version of the regional PAI. Therefore, when looking for data on landslide and flood hazard in Sardinia, one must necessarily take account of four datasets, two for each type of hazard, freely available from the Regional geoportal[8] and enlisted in Tab. 4: first, the most updated versions of the PAI maps; second, the maps commissioned by the municipalities and approved by the River Basin Authority. In the study area, for each hazard type the two spatial datasets partly overlap in twelve of the fifteen municipalities, while for three of them (Bari Sardo, Dorgali, and Baunei) a study at the municipal level has not been produced and approved so far. However, the area of interest for this research was analyzed within a study commissioned by the regional administration and approved in 2011[9] that led to an early revision of the Sardinian PAI, which means that both landslide and flood hazard data for the three aforementioned municipalities can be retrieved from the regional PAI, although in some parts of Dorgali's territory the landslide hazard map is void.

Title of the spatial dataset (original)	Content of the spatial dataset	Latest update	Metadata and download URL
Pericolo Geomorfologico Rev. 42 (Pericolo Frana PAI)	LH, PAI (revision 42)	31/01/2018	http://webgis2.regione.sardegna.it/catalogodati/card.jsp?uuid=R_SARDEG:eb38d6c0-b51f-4df1-acdc-f7a752e7664c
Art.8 Hg V.09 (Pericolo Frana Art.8)	LH assessment commissioned by the municipalities and approved by the River Basin Authority	31/01/2018	http://webgis2.regione.sardegna.it/catalogodati/card.jsp?uuid=R_SARDEG:127d7692-14c0-4d85-a364-62476a0a3cc9
Pericolo Idraulico Rev. 41 (Pericolo Alluvioni PAI)	FH, PAI (revision 41)	31/01/2018	http://webgis2.regione.sardegna.it/catalogodati/card.jsp?uuid=R_SARDEG:9b3a1b64-2a59-4658-98ed-7f6cec366128
Art. 8 Hi V.09 (Pericolo Alluvioni Art.8)	FH assessment commissioned by the municipalities and approved by the River Basin Authority	31/01/2018	http://webgis2.regione.sardegna.it/catalogodati/card.jsp?uuid=R_SARDEG:34d2c0f6-a8c3-4bcb-8a64-abbec8723574

Tab. 4 Landslide and flood hazard datasets used within this study.

Municipality	Approval of the LH & FH maps [year]	Study commissioned by
Bari Sardo	2011	Sardinian regional administration
Baunei	2011	Sardinian regional administration
Budoni	2012	Municipal administration
Cardedu	2013	Municipal administration
Dorgali	2011	Sardinian regional administration
Gairo	2014	Municipal administration
Girasole	2012	Municipal administration
Loiri Porto San Paolo	2012	Municipal administration
Lotzorai	2015	Municipal administration
Orosei	2013	Municipal administration
Posada	2010	Municipal administration
San Teodoro	2015	Municipal administration
Siniscola	2013	Municipal administration
Tertenia	2015	Municipal administration
Tortolì	2011	Municipal administration

Tab. 5 Municipalities included in the study area: approval date of the most recent hazard maps.

8 http://www.sardegnageoportale.it/webgis2/sardegnamappe/?map=pai

9 http://www.regione.sardegna.it/index.php?xsl=509&s=1&v=9&c=9305&tb=8374&st=13

As for the other twelve municipalities, in case of overlapping patches where the PAI and the municipal maps identify two different hazard levels[10], within this study we consider the latter, for the following three reasons: first, the municipal assessments and maps are more recent than the corresponding PAI ones; second, the municipal assessments and maps have already been approved by the River Basin Authority, which serves as a certification of their quality; third, the municipal assessments can in principle reply the PAI ones any time soon, whenever the River Basin Authority decides that they are to be integrated within a new revision of the PAI. For each municipality in the study area, Tab. 5 provides details on the most updated landside and flood hazard maps (bearing in mind that the PAI LH and FH maps concern all of the 15 municipal territories).
The rest of this section looks briefly at the nine independent variables and data used to map them.
Natval value was assessed though the InVEST model "Habitat Quality"[11] based on the following input data:

- land cover types as per the 2008 Regional land cover raster map;
- raster maps of ten spatial threats (cultivation; grazing; removal of forest undergrowth; salt works; paths, tracks, and cycling tracks; roads and motorways; airports; urbanized areas; discharges; fire and fire suppression). The threats were selected based on the Sardinian standard data forms for the Natura 2000 sites among those having spatial character;
- weights and decay distance for each threat from expert judgments;
- sensitivity of each land cover type to each threat from expert judgments;
- accessibility to sources of degradation, in terms of relative protection to habitats provided by legal institutions. The three categories we used are as follows: natural parks, areas protected and managed by the regional Forestry Agency, Natura 2000 sites.

Consval value was assessed using the following datasets:

- vector raster map of habitats of Community interest, provided by the Sardinian regional administration;
- Natura 2000 standard data forms, available as MS-Access database from the website of the Italian ministry for the environment, and land and sea protection[12];
- a regional monitoring (unpublished) report on the conservation status of habitats and species of Community interest, provided by the Sardinian regional administration.

Landsval was assessed using the spatial dataset of the Regional Landscape Plan, retrievable from the Regional geoportal[13], and providing the spatial distributions of areas protected because their environmental and/or cultural and historic qualities and significance.
Recrval was mapped using the InVEST model "Visitation: Recreation and Tourism"[14], which only requires the area of interest as input data, used by the tool to retrieve geotagged pictures uploaded by Flickr users within a chosen time frame.
For a full methodological account about the production of *Natval*, *Consval*, *Landsval*, and *Recrval* maps, the reader can refer to Lai & Leone (2017) and to Cannas et al. (2018).
With regards to *Agrofor*, the value of rural plots in 2017 was estimated using the 2018 CORINE land cover map[15] as spatial reference and two main datasets for agriculture and forestry areas, both providing monetary values of the land per unit of area. As for agricultural areas, a spreadsheet[16] produced by the National Research Council of Agriculture and Agricultural Economics was used, which provides the value of land parcels based

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10 This is possible because the regional and the municipal assessment have different spatial and temporal resolution, and the hazard level can vary over time: for instance, it can be lowered through appropriate mitigation interventions.

11 https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/habitat_quality.html

12 ftp://ftp.minambiente.it/PNM/Natura2000/TrasmissioneCE_dicembre2017/

13 http://www.sardegnageoportale.it/webgis2/sardegnamappe/?map=ppr2006

14 https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/recreation.html

15 https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

16 https://crea-qa.cube.extrasys.it/-/banca-dati-valori-fondiari-bdvf

on the type of crop, on elevation area, and on location (by taking provinces, i.e. Italian NUTS3 statistical regions, as the basic spatial units). As for forestry areas, data are available from the National Revenue Agency[17] and the values are here differentiated according to type of production, provinces, and rural regions (i.e., smaller spatial units contained within provinces).

The *LST* map was developed based only on Landsat 8 TIRS and OLI satellite imagery acquired in 2019, on August 11 and 20, and made available by the USGS's Earth Resources Observation and Science[18]. A full methodological account is provided in Lai et al. (2020b).

Variable	Input data	Input data source(s)	Tool	References
FH	• PAI FH maps • Municipal FH maps	Regional geoportal		---
LH	• PAI LH maps • Municipal LH maps	Regional geoportal		---
Natval	• Regional land cover raster map • Protected areas map	Regional geoportal	InVEST - Habitat quality model	Lai & Leone, 2017 Cannas et al., 2018
	• Threats to biodiversity (spatial data only)			
	• Expert judgments	Questionnaires		
Consval	• Habitats of Community interest	Regional administration		
	• Regional monitoring report			
	• Natura 2000 standard data forms	Environmental ministry's website		
Landsval	• Regional landscape plan dataset	Regional geoportal		
Recrval	• Study area	Regional geoportal	InVEST - Visitation: recreation and tourism model	
Agrofor	• 2018 Corine land cover map	Copernicus Land monitoring service		---
	• Land value (Agricultural areas)	National Research Council of Agriculture and Agricultural Economics' website		
	• Land value (Forestry areas)	National Revenue Agency's website		
LST	• Landsat 8 TIRS and OLI satellite imagery	USGS's Earth Resources Observation and Science's website	LST QGIS plugin by Ndossi & Avdan (2016)	Lai et al., 2020a Lai et al., 2020b
CO2Stor	• Regional land cover raster map	Regional geoportal	InVEST - Carbon storage and sequestration model	Floris, 2020
	• Carbon pool data	2005 National Inventory of Italian Forests		
		Regional pilot project on land units and soil capacity in Sardinia		
Altitud	• 10-m resolution Digital terrain model	Regional geoportal		---
Slope	• 10-m resolution Digital terrain model	Regional geoportal		---

Tab. 6 Spatial datasets developed for this study: input data, sources, tools, and references.

17 https://www.agenziaentrate.gov.it/portale/web/guest/schede/fabbricatiterreni/omi/banche-dati/valori-agricoli-medi/valori-agricoli-medi-sardegna

18 USGS. Science for a Changing World—EarthExplorer: https://earthexplorer.usgs.gov

The carbon dioxide capture and storage capacity (*CO2Stor*) map was produced using the InVEST "Carbon Storage and Sequestration" model[19] fed with the regional 2008 land-cover map coupled with look-up tables associating land covers to three carbon pools as follows: i. above-ground biomass, ii. soil organic content, iii. dead organic matter; a fourth carbon pool (concerning below-ground biomass) can actually be fed into the model, but no information was available. Data for the three remaining carbon pools was gathered from the 2005 National Inventory of Italian Forests[20] and from a regional pilot project concerning land units and soil capacity in Sardinia[21]. For a full methodological account, the reader can refer to Floris (2020).

Finally, elevation (*Altitud*) and slope (*Slope*) were retrieved from the 10-m resolution digital terrain model available from the Regional geoportal[22].

For each variable, Tab.6 summarizes data inputs and their sources, tool employed (when available; otherwise, ordinary GIS tools were used), and references.

Finally, through rasterization of vector maps and resampling of raster maps, a 30-m resolution raster map was developed for each variable; by overlaying such maps, an attribute table providing for each cell the corresponding value of each variable was produced to feed the regression model presented in Section 2.2.

Fig.2 provides a complete overview of the methodology presented in Sections 2.2 and 2.3.

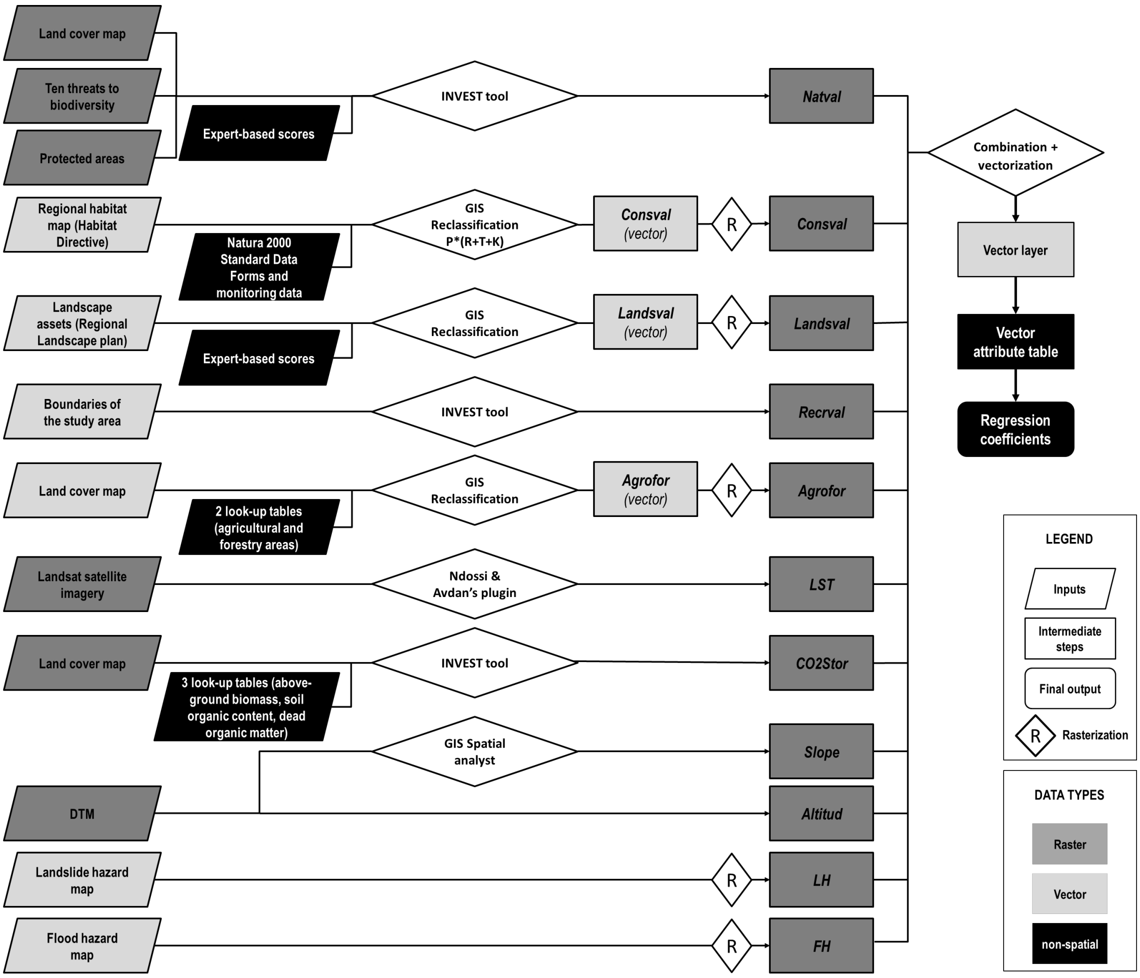

Fig. 2 Full overview of the methodology.

[19] https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/carbonstorage.html

[20] https://www.sian.it/inventarioforestale/

[21] http://www.sardegnageoportale.it/index.php?xsl=2420&s=40&v=9&c=14481&es=6603&na=1&n=100&esp=1&tb=14401

[22] http://www.sardegnageoportale.it/areetematiche/modellidigitalidielevazione/

3. Findings

This section contains two subsections. In the first, the spatial features of the hazard-related dichotomous variables and of the covariates of the Logit models are presented. In the following subsection, the estimates of the models are described and discussed.

3.1 Flood and landslide hazards and their drivers

Fig. 3 provides the spatial distribution of both dependent (left hand side panel) and independent (right hand side panel) variables.

Very high landslide hazard values concern less than the 5% of the study area; as the map shows, they form elongated clusters along the southwest-northeast direction due to geological and geomorphological reasons, along deep canyons in the Baunei, Dorgali, and coincident with the northern side of the Monte Albo karst mountain chain in Siniscola. Nearly 15% of the study area is classed as high hazard, while most of the study area is classed as either medium (about 25.5%) or moderate hazard (circa 40%). Only about 6% of the study area is classed as having no landslide hazard, while in the remaining part (approximately 8.5%), included in the municipality of Dorgali, landslide hazard was not assessed and mapped.

As for flood hazard, 90.5% of the study area shows null values; in the remaining parts, its level is mostly (6%) very high. The remaining 3.5% concerns high, moderate and low values. This is because flood hazard usually takes the maximum value in correspondence to riverbeds, river estuaries, coastal wetlands and their closest surroundings, while its level decreases (more or less quickly depending on factor such as morphology or soil type) as the distance increases. As shown in Fig. 3, flood hazard is mostly found to the south and the north of the study area, and almost absent in the central part.

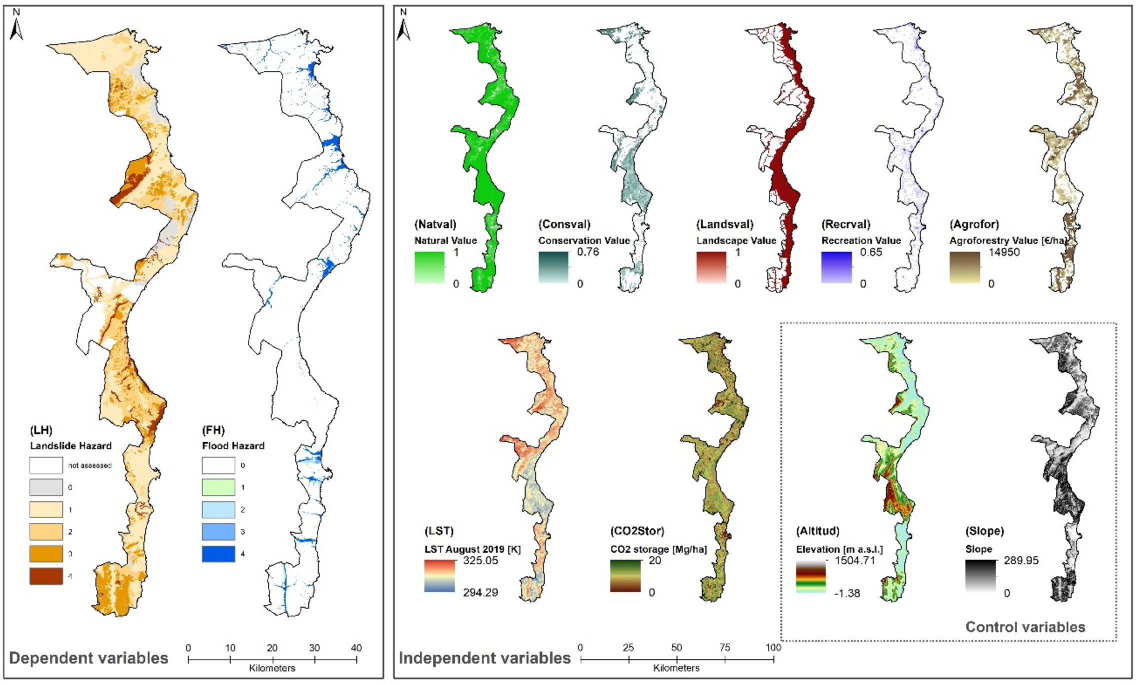

Fig. 3 Spatial distribution of dependent and independent variables in the study area.

Concerning the independent variables, *Natval* takes extremely high values in most of the study area (around 72.8%) and medium values in around 23.5%, while the null value only concern the remaining 3.7% circa of the study area, corresponding to artificial surfaces such as villages and towns' footprints.

Consval, which in principle can range in the 0–1 interval, in the study area takes 0.76 as maximum value and it is null in around 61% of the territory. This is because habitats of Community interest are identified and mapped mostly within Natura 2000 site, while comprehensive assessments outside the network are missing. It is therefore not surprising that non-zero values are mostly found in the central part of the study area, hosting one of the largest Sardinian Special Conservation Area (ITB020014 "Golfo di Orosei").

Landsval is null in approximately 47.5% of the study area and, as clearly visible in Fig. 3, takes the highest values along the coastline, because the Regional Landscape Plan strictly protects coastal landscapes, and along some the main rivers and creeks, also protected under the national landscape law.

Recrval takes the null value in most of the study area (around 78.3%), meaning that no geotagged pictures were uploaded onto Flickr in these areas. Non-zero values can be found mostly along the coastline and usually peak close to the towns and to coastal facilities, although in Dorgali and Baunei, well-renowned among hikers and climbers for their outstanding natural characters, lighter shades of blue in Fig. 3 are visible also in inner areas across their territories.

Agrofor is null in nearly a half (49.4%) of the study area. The highest values are observed in the southern and northern parts of the study area, especially in river valleys and coastal plains, as far as agricultural activities are concerned.

LST hot and cold values are quite clustered, and the clusters mostly correspond to those having high elevation or high slope values, as the maps in Fig. 3 show.

Finally, *CO2Stor* ranges between zero and two Mg per hectare, with more than 61% of the study area above 1 Mg/ha, while low values are clustered mainly along the coastline to the north and along rivers and wetlands to the south.

3.2 Estimates of the Logit models

Tab. 7 and 8 show the results of the estimates of the Logit models related to the dichotomous variables FH and LH, and its correlations with the seven environmental features which characterize the RGI. The outcomes partly differ for the two variables, and the differences can be explained through the environmental profiles of the two types of hazards.

Variable	Marginal effect	z-statistic	p-value
Marginal impact on FH=1 probability, $\partial Prob(FH=1)/dx_i$, Prob (FH=1) = 9.00%			
Natval	-0.0043	-13.042	0.0000
Consval	0.0132	22.859	0.0000
Landsval	0.0113	30.012	0.0000
Recrval	-0.0042	-1.867	0.0619
Agrofor	0.0014	36.580	0.0000
LST	-0.0020	-35.729	0.0000
CO2Stor	-0.0055	-21.299	0.0000
Altitud	-0.0001	-72.983	0.0000
Slope	-0.0003	-22.713	0.0000
Log-likelihood goodness-of-fit test			
Log-likelihood ratio = 72946.20 – Prob. > chi-square = 0.00000 (9 degrees of freedom)			

Tab. 7 Marginal effects on the probabilities of FH=1 of variables described in subsection 2.3, whose definitions and descriptive statistics are reported in Tab. 2

In the case of *FH*, *Natval* and *Consval* reveal opposite impacts on the probability of a parcel to be associated either to a relevant or to a weak hazard condition. *Natval* shows a positive correlation to hazard decrease, i.e. a negative marginal effect, whereas *Consval* reveals a negative correlation, or a positive marginal effect.

The estimates of the Logit model concerning *LH* show the opposite correlations.

Secondly, *Recrval* and *Landsval* reveal impacts on the probability of weak flood and landslide hazards consistent with each other and positive, which indicates that these two features of the RGI should be enhanced and strengthened in order to promote prevention and control. This implies that environmental and cultural attractiveness, and identification and protection of landscape and cultural resources, should be targeted as points of reference to fight environmental hazard. Thirdly, the impacts of *Agroforest* on *FH* and *LH* are opposite as well. Agricultural and forestry productive land shows a positive impact on decrease of landslide hazard and likewise a negative effect on flood hazard. As a consequence, effective control on environmental hazard implies that the most productive agricultural and forestry activities should not be located close to floodplains and their surroundings, where agricultural and forestry land should be used just to counter flooding. Productive agriculture and forestry should be implemented elsewhere, and in particular near areas characterized by a relevant landslide hazard.

Variable	**Marginal effect**	**z-statistic**	**p-value**
Marginal impact on LH=1 probability, $\partial Prob\ (LH=1)/dx_i$, Prob (LH=1) = 44.80%			
Natval	0.3351	64.191	0.0000
Consval	-0.2787	-46.522	0.0000
Landsval	0.0155	7.137	0.0000
Recrval	-0.6352	-12.970	0.0000
Agrofor	-0.0170	-56.433	0.0000
LST	-0.0274	-72.544	0.0000
CO2Stor	0.0533	17.930	0.0000
Altitud	0.0002	44.439	0.0000
Slope	0.0087	128.132	0.0000
Log-likelihood goodness-of-fit test			
Log-likelihood ratio = 122653.10 – Prob. > chi-square = 0.00000 (9 degrees of freedom)			

Tab. 8 Marginal effects on the probabilities of LH=1 of variables described in subsection 2.3, whose definitions and descriptive statistics are reported in Tab. 2

The sixth characteristic of the RGI is *LST*, which is an indicator of how, and to what extent, land covers help to mitigate negative phenomena such as heat islands and waves, and to improve the quality of the rural and urban environments (Lai et al., 2020a). As in the cases of *Recrval and Landsval*, the estimates of the two Logit models reveal impacts on the probability of weak flood and landslide hazards consistent with each other and positive, which indicates that this feature of the RGI does not need particular attention in terms of landslide and flood hazard control. Indeed, the estimates of the Logit models imply that the higher the *LST*, the lower the two hazards. Since the question related to LST as regards climate regulation focuses on policies to decrease *LST*, it can be concluded that the issue of *LST* is not connected to control landslide and flood hazards.

Furthermore, *CO2Stor* shows opposite impacts on the probability of a parcel to be associated either to a relevant or to a weak hazard condition. This is entirely consistent with expectations, since, in the case of flood hazard, areas vegetated and rich in soil are likely to increase the probability of weak hazard, since they work as drainage areas to absorb excess flooding and filter sediment, whereas, in the case of landslide hazard, the positive impact on the probability of hazard increase is likely to be connected to the fact that areas rich in soil are comparatively more suitable to debris flow, especially in zones characterized by steep slopes. That being so, adequate monitoring of environmental hazard implies that the RGI should encourage the conservation of vegetated and rich-in-soil areas in the surroundings of floodplains, even though not used as croplands, as it is put in evidence above as regards the impacts on flood hazard by *Agrofor*, while the most productive agricultural and forestry activities should be located not close to floodplains and their surroundings, and likewise not close to zones featured by steep slopes.

Finally, the estimated marginal effects of the two control variables, *Altit* and *Slope*, reveal the expected signs in both cases, since, on the one hand, it is expected that the lower the altitude and the lower the slope, the higher the probability of severe flooding to take place, whereas the higher the altitude and the higher the slope, the higher the probability of serious landslide events. Moreover, all the estimated marginal effects are significant in terms of p-values, and, in general, the marginal effects on the probability of relevant flood hazard are much lower than the impacts on the probability of relevant landslide hazard since the cumulative probability of relevant flood hazard (lower than 10%) is much lower than the cumulative probability of relevant landslide hazard (about 50%). The goodness of fit of the estimates of the two models are excellent, as shown by the two log-likelihood ratios measures.

4. Discussion

The methodological approach proposed in this study analyzes the relations between RGI and environmental hazards, represented by landslides and floods. In particular, the study focuses on nine variables that are here regarded as proxies for the RGI functions. The results imply the definition of planning policies based on ecosystem service conservation and enhancement (Baskent, 2020). The estimates of the Logit models highlight some issues worth discussing.

Landslides are more likely to occur in areas characterized by high natural values (Zhang et al., 2018) and their negative impacts as regards these areas entail relevant systemic effects with respect to the complex environmental matrices which characterize such areas (Yousefi et al., 2020), particularly sensitive to landslides and floods (Dragicevic et al., 2011).

Areas characterized by high values of *Consval*, such as Natura 2000 sites, show a higher probability of flood hazard occurrences. Natural and semi-natural zones located within protected areas mitigate flood hazard and its potential negative impacts by providing permeable surfaces characterized by the presence of vegetation that absorbs floodwaters. Conservation planning theory focuses on the concept of vulnerability, and deems the establishment of a widespread network of protected areas, such as Natura 2000, as a key planning tool to protect natural ecosystem services and mitigate natural hazards (Turner et al., 2007). Recent natural disasters caused by floods have demonstrated how past planning choices have drained, dammed and diverted watercourses not paying any attention to the involved delicate environmental matrices (Stolton et al., 2008; Isola & Leone, 2019). Moreover, protected areas are characterized by natural vegetation, such as forests, which prevent or mitigate landslides, snowslides and avalanches (Stolton et al., 2008). According to Guareschi et al. (2020), natural and conservation values represent the potential capability of biodiversity to provide ecosystem services despite threats and pressures. Therefore, analyzing the probability of an area to be associated to specific hazard conditions is essential to the spatial and sustainable development of the area and to define appropriate planning choices aimed at protecting the environment (Dragicevic et al., 2011).

High values of *Recrval* and *Landsval* are mainly concentrated in coastal areas characterized by significant environmental, social, and cultural qualities. As a result, in these areas planning policies and strategies are fundamental in order to mitigate the effects of flood and landslide hazard, especially in relation to problems concerning coastal erosion that affects the entire Sardinian regional coastal zones. Damages caused by floods and landslides threaten the integrity of coastal areas, whose protection requires a great effort to balance development pressures, and economic and environmental sustainability. According to the UNESCO's final report on the "Results of the second cycle of the periodic reporting exercise for the Europe Region and Action Plan" (UNESCO, 2015), landscape and cultural resources are extremely exposed to the adverse effects of natural hazards. This problem is also highlighted in the "Sendai Framework for disaster risk reduction 2015–2030" (United Nations, 2015), whose vision aims at supporting the implementation of the 2030 Agenda for Sustainable Development, one of which objectives is to "strengthen efforts to protect and safeguard the world's cultural and natural heritage" (Goal n. 11, target 11.4). In this regard, the study proposed by Ravankhah et al. (2019) is worth mentioning, because it defines a "taxonomy of natural hazards in relation to cultural heritage based on a theoretical and conceptual framework" (p.1). By taking historic center of Réthymno, in Crete, as a case study, the authors identify and analyze those hazards that are likely to generate damages to the historic elements of the towns in order to support decision-making processes in designing and implementing mitigation interventions.

As regards *Agrofor*, the findings suggest that agricultural and forestry land should be used only to face flooding (O'Connell et al., 2007), while the productive use of agricultural and forestry areas should be implemented elsewhere. However, riparian areas are particularly productive and, therefore, profitable for farmers due to their proximity to water resources. The study by Fedele et al. (2018), by looking at the provinces of West Kalimantan and Central Java in Indonesia, suggests that natural hazards ought to orient adaptation strategies in local contexts so as to reduce risks to which affected people are exposed; among such strategies, the authors propose to implement land use changes that entail trade-offs in the provision of different types of ecosystem services. Such aspects have to be carefully analyzed when designing policies to enhance the quality of RGI.

In relation to *CO2Stor*, the study's outcomes are entirely consistent with the findings of several studies which put in evidence direct positive correlations between carbon capture and storage, and mitigation of the impacts of climate change through abatement of greenhouse gases (among many, Aminu et al., 2017; Floris & Zoppi, 2020).

According to the European Environment Agency (2015), the role of RGI in mitigating the impacts of natural hazards is crucial (Salata et al., 2016). Indeed, the role that RGI plays in mitigating flood hazard in relation to *Natval* is straightforward; however, in the case of floodplains flood hazard the RGI should encourage the negative sign of *Natval* puts in evidence that encouraging conservation of vegetated and rich-in-soil riparian areas may possibly be associated to a decrease in the potential capability of biodiversity to supply final ecosystem services.

Furthermore, the issue of the potential damage generated by the interaction of different types of hazard should be carefully taken into consideration (Yousefi et al., 2020) when designing and implementing risk-reduction projects at the regional and local scales (Pourghasemi et al., 2020).

5. Conclusions

A number of policy implications and recommendations can be derived from the outcomes of the study.

The results concerning the influence of *Natval* and *Consval* on the probability of comparatively higher flood and landslide hazards imply that, in case of landslide hazard, prevention and control should target areas with a relevant natural value, that is, areas endowed with a significant potential supply of ecosystem services, while, in case of flood hazard, they should focus on areas featured by the presence of natural habitats types of Community interest, as identified under the Habitats Directive. Since areas showing high values of *FH* are mostly concentrated in the floodplains and their surroundings, while areas having high values of *LH* are widespread over the study area, and, in more general terms, over the whole Sardinian island, these findings entail different implications concerning prevention and control hazards when defining spatial planning policies to implement the RGI. That being so, the definition and implementation of the RGI should carefully study and develop spatial policies related to waterways and their surroundings, which should entail strict regulations related to anthropic access and visits in floodplains areas characterized by significant values of *Consval*, i.e. by a relevant concentration of habitats of Community interest. Moreover, the RGI-related spatial policies should carefully balance the relationship between *Natval* and landslide hazard, that is, they should address the issue of the exploitation of natural ecosystem services located in areas endowed with high supply potentials, and likewise characterized by a relevant landslide hazard. This is entirely consistent with the position of the Commission of the European Communities, which recommends that "working with nature's capacity to absorb or control impacts in urban and rural areas can be a more efficient way of adapting than simply focusing on physical infrastructure" (Commission of the European Communities, 2009, p. 5). Since Natura 2000 sites within Sardinia include most coastal wetlands, estuaries, waterways, and large stretches of coastal areas, it is pretty straightforward that parcels located in these areas should show a relevant impact on flood hazard. Spatial planning policies should therefore include strict regulations related to new settlement development in floodplains, oriented to protect nature and natural resources belonging to riparian areas and their surroundings, which are characterized by high figures of *Consval*. Consistently with these observations, the Lower Danube Green Corridor Agreement focuses on the restoration of around 2,000 square kilometers of floodplains, side channels and associated habitats along the Danube as a control measure to mitigate the destructive impacts of floods in the region. The estimated cost (about 50 million euros) is lower than the cost related to the environmental damages caused by floods in 2010 (European Commission, 2010).

The impact of *Natval* on the probability of high landslide hazard entails that spatial policies should protect forests, which exert a relevant action to mitigate soil erosion, surface water runoff and slope instability, and, in so doing, to reduce landslide hazard (Trigila et al., 2018). Moreover, silvicultural activities generate outstanding negative impacts on forests if they neglect best available practices related to forest management (Siry et al., 2005). In terms of ecological stability, high forests should be preferred, with the exception of areas characterized by high values of *LH*, high slopes and low soil power, where shrub species are expected to be more suitable. Furthermore, forest road systems require appropriate planning, implementation, and maintenance in order to avoid concentration of surface water runoff and erosion, and triggering of landslides along the slopes (Sapač et al., 2017).

The outcomes of the regression model imply that forestry activities should be favored in riparian areas and their surroundings to mitigate flood hazard, while agricultural uses should be moved to more distant locations. Agriculture displacement may possibly be implemented by means of incentives, assigned to low rent farmers in order to become forest farmers (Lai et al., 2020a). Moreover, maintenance interventions in agriculture and forestry contribute to mitigating flood hazard. In areas characterized by arable land-pasture, terraces or permanent non-terraced crops, agro-forestry-pastoral interventions may entail benefits in terms of soil conservation, such as applications of specific innovative agricultural practices, crop diversification or buffer strip systems between agricultural areas and waterways (Regione Piemonte, 2018).

Spatial planning policies are potentially powerful in terms of mitigation of flood and landslide hazards (Hartmann & Spit, 2015); however, the normative frameworks of water resource management and soil protection are quite inconsistent with each other. At the European level, the EU Water Framework Directive (Directive 2000/60/EC) and the European Directive on the Assessment and Management of Flood Risk (Directive 2007/60/EC) represent the statutory policies concerning water resource planning and management at the European level. As for landslide hazard, a European normative framework is still missing. At the Italian national level, notwithstanding the approval of some specific laws, such as the already mentioned no. 183/1989 and no. 267/1998, a comprehensive and integrated normative system related to protection from landslide and flood hazards is missing as well, and the Italian legislation mainly focuses on water catchment management. Sardinia is characterized by high landslide and flood hazards (Trigila et al., 2018), and its hydrogeological structure is quite unstable due to natural phenomena and anthropic actions. The Sardinian government has designed three regional plans concerning landslide and flood hazards: the already mentioned PAI in 2006, focusing on protection and conservation of soils and on prevention and management of landslide and flood hazards; a management plan for riversides and their surrounding areas in 2015; and finally a flood risk management plan consistent with the Directive 2007/60/EC in 2016, aimed at mitigating negative consequences of floods on life quality, environment, cultural heritage, and social and economic activities.

Moreover, the methodological approach implemented in this study shows two innovative aspects. Firstly, the relationship between flood hazard and the implementation of GI is assessed at the regional level, whereas the current literature mainly uses municipal and sub-municipal frameworks to analyze their interdependence, for instance, by making reference to green roofs and permeable pavements. The regional scale is much more suitable to deal with the integration of environmental hazards management and GI implementation, in terms of planning policy, awareness-building and decision-making processes. Secondly, the methodological approach uses data that are easily accessible to researchers, policy makers, and practitioners, and comparatively cheaper than complicated microeconomic estimates, in terms of both costs and time.

In conclusion, the methodological approach proposed in this study may represent a tool in support of spatial decision-making processes that can be exported to other European contexts, due to its adaptability to the national planning and normative framework, on the basis of the European legislation concerning protection and improvement of nature and natural resources.

The implemented methodology is effective in supporting civil officers, practitioners, and local public authorities to deal with the impacts of land cover and land use changes. From this perspective, the integration of GI-related and environmental planning policies may represent a basis to drive local decision-making processes towards prevention or, at least, mitigation of damages generated by landslides and floods, and towards the establishment of appropriate regulations.

Promising directions for future research can be identified as follows. A particular focus should be given to building a new normative framework to implement the RGI conceptual and technical category, conceived as a provider of ecosystem services, into the theoretical and technical approaches of the European and national spatial planning practices.

Moreover, a relevant profile to be explored is represented by the role of local communities as regards the definition and implementation of planning processes aimed at managing environmental hazard through policies related to ecosystem service protection and enhancement. These processes should be based on the progressive improvement of the scientific, technical, and cultural expertise of the local societies concerning the provision of goods and services generated by the ecosystems, and are identified by the category of urban bioregion (Magnaghi, 2019). In this conceptual framework, the communities' incremental awareness can be identified as a main driver of the qualitative improvement of the spatial, environmental and landscape heritage at the local level. Under this perspective, mitigation and control of landslide and flooding hazards can be included in the planning practices implemented by the local governments representing societies fully aware of the importance of nature and natural resources as regards their potential in terms of life quality improvement (Magnaghi, 2020).

Authors' contribution

Sabrina Lai (S.L), Federica Isola (F.I.), Federica Leone (F.L.), and Corrado Zoppi (C.Z.) collaboratively designed this study. Individual contributions are as follows: F.I. and F.L. jointly wrote Section 1; S.L. wrote Sections 2.1, 2.3, and 3.1; C.Z. wrote Sections 2.2, and 3.2; F.I. wrote Section 4; F.L. wrote Section 5.

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Conflicts of Interest: The authors declare no conflict of interest.

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Environmental quality of emergency areas. A methodology to assess shelter areas liveability

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Abstract

The types of risk that territories are facing today have greatly increased in recent years, having multiplied the damage that human activity has produced and continues to produce on the natural environment. With the aim to create a really resilient territory it is necessary to carry out an environmental quality assessment together with risk analysis, in order to build effective responses to the possible problems resulting from the changes in progress. This assessment should be integrated into the knowledge framework of existing planning tools, in particular as regards the Emergency Plan. Among the Plan contents, indeed, the identification of the areas for the accommodation of population affected by disaster is included. Nevertheless, currently localization criteria are mainly used, without considering the potential liveability of these areas. This document presents the first results of a research aimed at identifying and assessing the factors useful to ensure an adequate environmental quality of the shelter areas, defined following the comparative study of evaluation systems used in different countries. Research aims to provide opportunity for broader reflection on the relationship that needs to be established between these evaluation systems and planning tools, in respect of which there is at present almost total independence.

Keywords

Environmental quality; Assessment; Emergency planning.

How to cite item in APA format

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1. Introduction

There are whole regions in Europe and in the world that, due to their geographic location, have always been exposed to several types of natural risks such as seismic and volcanic ones (Gargiulo & Lombardi, 2016). Emergency planning has a fundamental role in fragile territories such as Italy, where a large proportion of the population is exposed to various risks1. Emergency Plan defines the set of operational intervention procedures to deal with any disaster expected in the territory. It is a dynamic, flexible, and constantly updated tool, having to take into account the evolution of land use planning and changes in the expected scenarios. The Plan in structured in several sections, among which the one related to emergency management is certainly the most characteristic. However, the analysis of the territory and the consequent construction of the knowledge framework is fundamental for the prefiguration of the scenarios and for the preparation of the related intervention activities linked to the occurrence of the expected disaster. In this regard, the assessment of the existing risks only is not enough to provide a comprehensive representation of the analysed territory (Papa et al., 2015). Cognitive action needs to be increased by further analysis that consider the environmental quality of the site, on the basis of which define its ability to adapt to change and to react to it. The definition of the environmental quality of the territory is useful for the identification of the so-called emergency areas, with special regards to the shelter areas, that are intended to accommodate population affected by disasters for a medium-long period. Currently, localisation parameters are mainly used for the identification of these areas, such as the proximity to the main road network, to the essential services, etc.

This study investigates parameters characterizing the environmental quality of a site through the comparison of different evaluation systems existing in the literature, and how the assessment of these parameters can relate to the existing emergency planning tool. Analysis results are tested on the shelter areas identified by the Emergency Plan of the city of Bologna, by evaluating if their environmental conditions are suitable to host people for medium/long time.

2. Background concerning environmental quality

The environmental quality of an area or of a territory determines its living conditions, ensuring the well-being and protection of human health. The assessment of environmental quality is very often put in the background or completely bypassed during the development of knowledge processes prior to the planned choices, because analysis is mainly focused on the type and extent of natural risks existing in the examined area. Data concerning risks exposure are indispensable components of the knowledge framework, nevertheless nowadays they represent a necessary but not sufficient condition for an adequate and integrated understanding of a territory. The environmental issue, indeed, is one of the greatest problems of the current century due to the serious consequences linked to the deterioration of the quality of life and the health problems that it entails (Orhan, 2012). It can be interpreted as the combined effect of individual elements, the diversity and multiplicity of which motivates the search for synthesis indicators that can streamline the analysis without causing an excessive loss of information (Aiello et al., 2015). However, no generally accepted conceptual framework or coherent system to measure and assess properly environmental quality aspects has been developed to date (Kazemzadeh-Zow et al., 2018).

Starting from these assumptions, the primary objective of the research was to create a "mosaic" of the various parameters that contribute to the definition of the environmental quality of a territory and to identify for each of them the most representative indicators, in order to provide an unified, analytical, and reliable evaluation method. A comparative analysis of the most relevant international and national voluntary certification systems

[1] In Italy 41% of the total population lives in in areas with medium or high seismic risk, 2% in areas with high landslide risk and 3% in areas with high flood risk (Trigila et al., 2015; Di Giovanni, 2016).

has been carried out with this aim[2]. A cross-study of European and national legislation has been carried out for each defined indicator, to obtain a regulatory reference regarding the related threshold values.
The study was developed through appropriate key questions, thanks to which the analysis and the results have been structured[3]. Following data emerged as response to key questions. The parameters characterizing environmental quality can be identified as follow: air quality, water quality, light pollution, noise pollution, heat island effect. Measurement indicators and related assessment method have been defined for each parameter (Tab. 1). Indicators in Tab. 1 express the environmental condition at the *t* time of the measurement (*state indicators*). Therefore, results of the assessment are not static but susceptible to change.

3. Materials and methods

3.1 Case studies

Shelter areas identified by Municipal Plan of Civil Protection of the city of Bologna (regional capital of Emilia-Romagna, Italy) have been selected as case studies. The choose was based on the data availability and on the representativeness of the city of Bologna, which plays a strategic role in emergency conditions being the heart of a metropolitan area populated by over a million inhabitants. The Plan identifies nine shelter areas (Fig. 1), which "must contain at least 500 persons and field services, not be exposed to risks and be equipped with all essential services, or in any case located close to electricity and water supply, and to pipelines for wastewater disposal" (Municipal Plan of Civil Protection of the city of Bologna, 2016). Areas identification criteria refers only to the risk conditions and functional equipment. The aim of this work is to verify if shelter areas identified by the Plan also meet the environmental quality requirements necessary to ensure satisfactory livability levels. The final output will be a synthesis map built through the assessments carried out by using indicators in Tab.1.

3.2 Methods

Work was structured following the flowchart in Fig. 2. Actions can be grouped in four "blocks": (i) literature critical analysis and related outputs, (ii) input dataset creation, (iii) statistical analysis, and (iv) final output.
The first block refers to that described in Section 2.
After the definition of parameters characterizing environmental quality and related indicators, the dataset relative to the case studies has been created. The data needed to measure indicators have been extracted from different sources. Indicators for which sufficient data were not available were excluded from the dataset. Subsequently, indicators for which there was no variability of data between case studies were also excluded from the consecutive analyses (Tab. 2).
Data integration, indeed, was developed through Principal Component Analysis (PCA) that is a statistical analysis technique that allows to integrate data from different sources, and to reduce the number of correlated variables into a smaller number of uncorrelated components (Principal Components, PCs) maintaining the most of the data variance (Jensen, 2005; Faisal & Shaker, 2017). The PCs are linear transformations of the initial variables, able to explain the maximum possible share of the total variability through appropriate vectors of weights (loadings) assigned to the initial variables.

[2] DGNB System Basics for Urban Districts/Office and Business Districts (Germany), BREEAM Communities (UK), CASBEE for Cities (Japan), LEED for Neighborhood Development (USA), ITACA Protocol at Urban Scale, and GBC Neighbourhoods Certification System (both Italian) have been analysed.

[3] See Margiotta, N., Palermo, A. & Viapiana M.F. (2020). Qualità ambientale: metodologie di valutazione e strumenti di pianificazione. In M. Francini, A. Palermo & M.F. Viapiana (Eds.). *Il piano di emergenza nell'uso e nella gestione del territorio*, 307-321, Milano: Franco Angeli editore. ISBN 9788897190972 for a more detailed description of the carried out analysis.

Parameter	Certification System	Reference indicators	Normative references	Measurement indicators	ID	Assessment method
Air quality	DGNB	SOC1.9	European Directive 2004/107/CE European directive 2008/50/EC D.Lgs. 55/2010	SO2 concentration NO2 concentration NOx concentration PM10 concentration PM2.5 concentration Pb concentration B6H6 concentration CO concentration As concentration Cd concentration Ni concentration C20H12 concentration	$SO2_{conc}$ $NO2_{conc}$ NOx_{conc} $PM10_{conc}$ $PM2.5_{conc}$ Pb_{conc} $B6H6_{conc}$ CO_{conc} As_{conc} Cd_{conc} Ni_{conc} $C20H12_{conc}$	The concentration values (µg/m3) of each pollutant are detected and compared with the related limit values, target values, and upper and lower assessment thresholds established by European directives.
	BREEAM	RE07				
	GBC-LEED	[-]				
	CASBEE	Q1.2.1				
	ITACA	5,06 5,07 5,08 5,09				
Water quality	DGNB	ENV1.7	European Directive 2000/60/CE as amended D.Lgs. 152/2006 as amended DM 260/2010	Surface water bodies ecological status Surfacewater bodies chemical status Groundwater bodies quantitative status Groundwater bodies chemical status	ES_SWB CS_SWB QS_GWB CS_GWB	Ecological status (high, good, moderate, poor, or bad) and chemical status (good or falling to achieve good) of surface water bodies and quantitative status (good or poor) and chemical status (good or poor) of groundwater bodies are detected and assessed.
	BREEAM	LE03				
	GBC-LEED	[-]				
	CASBEE	Q1.2.2				
	ITACA	5,02 7,03.4				
Light pollution	DGNB	SOC1.9	Standard UNI 10819 *Model Lighting Ordinance* (MLO) (Ida & IES, 2011)	Number of lighting structures according to standards/lighting structures total number	$Ls_{0\%}/Ls_{tot}$	Lighting structures present in the area are detected, and the percentage deviation between the number of lighting structures whose luminous flux has dispersion upwards below the permitted limits (0% according to the MLO) and the total number of lighting structures is assessed.
	BREEAM	SE16				
	GBC-LEED	Credit 17 of *Sustainable Infrastructure and Buildings* Category				
	CASBEE	[-]				
	ITACA	5,05				
Noise pollution	DGNB	SOC1.9	European Directive 2002/49/CE L. 447/1995 DPCM of 1 March 1991 DL 194/2005.	L_{den} mean value L_{night} mean value	L_{den_mean} L_{night_mean}	L_{den} and L_{night} value are detected. Mean values of noise indicators are calculated for the examined area, by weighting L_{den} and L_{night} values against the extent of the surfaces characterised by each noise level. Mean values are compared with the related limit values.
	BREEAM	SE04				
	GBC-LEED	Credit 16 of *Neighbourhood management and programming* Category				
	CASBEE	[-]				
	ITACA	[-]				
Heat island effect	DGNB	ENV1.5 SOC1.1	DM of 11 January 2017.	Albedo mean value	Alb_{mean}	Examined area is divided into homogeneous sub-zones and related solar reflection coefficient (Albedo) is identified. An Albedo mean for the area value is calculated, by weighting Albedo values against the extent of each homogeneous sub-zone.
	BREEAM	SE08				
	GBC-LEED	Credit 9 of *Sustainable Infrastructure and Buildings* Category				
	CASBEE	[-]				
	ITACA	4,04 7,02.3				

Tab.1 Environmental quality parameters and assessment indicators

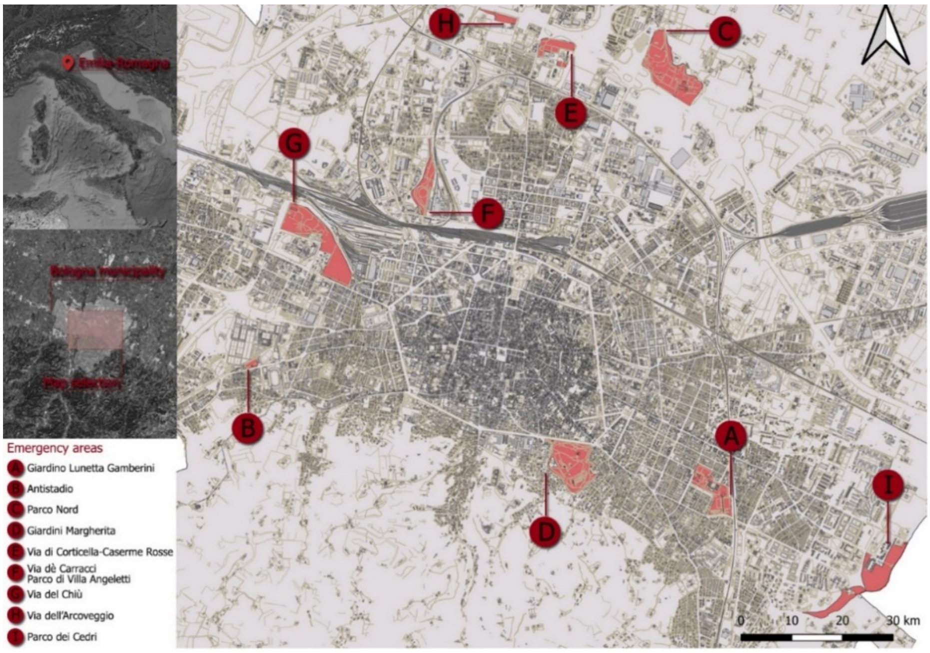


Fig.1 Localization of Bologna municipality and of shelter areas

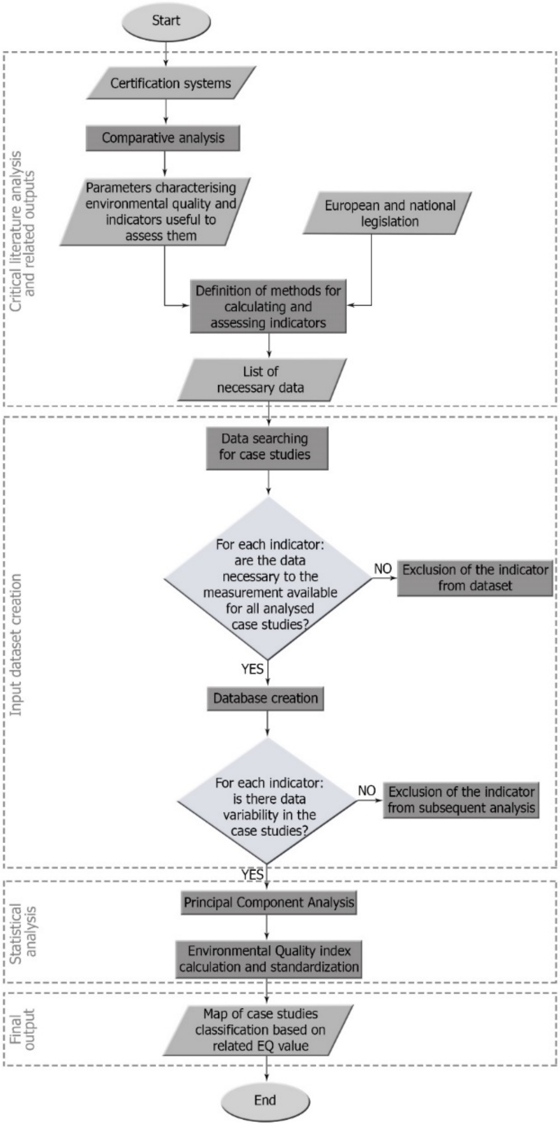


Fig.2 Overall flowchart

Parameter	Indicators	Source	Indicators excluded due to the lack of data	Indicators excluded due to the lack of variability in the data
Air quality	$SO2_{conc}$, $NO2_{conc}$, NOx_{conc}, $PM10_{conc}$, $PM2.5_{conc}$, Pb_{conc}, $B6H6_{conc}$, CO_{conc}, As_{conc}, Cd_{conc}, Ni_{conc}, $C20H12_{conc}$	*Regional agency of prevention, environment, and energy* (Arpae) of Emilia-Romagna	$SO2_{conc}$, NOx_{conc}, Pb_{conc}, $B6H6_{conc}$, CO_{conc}, As_{conc}, Cd_{conc}, Ni_{conc}, $C20H12_{conc}$	$PM10_{conc}$
Water quality	ES_SWB, CS_SWB, QS_GWB, CS_GWB	*Regional agency of prevention, environment, and energy* (Arpae) of Emilia-Romagna Water management Plan of Emilia-Romagna, retrieved from minERva web portale	[-]	ES_SWB, QS_GWB
Light pollution	$Ls_{0\%}/Ls_{tot}$	Google Earth Pro	[-]	[-]
Noise pollution	L_{den_mean}, L_{night_mean}	Strategic noise map of Bologna Agglomeration	[-]	[-]
Heat island effect	Alb_{mean}	Google Earth Pro	[-]	[-]

Tab.2 Data source and excluded indicators

The PCA requires the building of the covariance matrix between variables (indicators). When – as in this case – variables have different measurement units Pearson correlation matrix is used, in which each element *ij* (Pearson correlation index) is the ratio of the covariance of the variables *i* to *j*, and the product of the standard deviations of the two variables:

$$\rho_{ij} = \frac{\sigma_{ij}}{\sigma_i * \sigma_j} \tag{1}$$

For this reason, variables (indicators) with zero standard deviation (no variability) have been excluded. Then the eigenvalues and eigenvectors of the correlation matrix are calculated, and the number of PCs to be used is defined by using three Heuristic criteria. Based on the first criterion, the number of PCs to choose is equal to the number of eigenvalues that represent 80-90% of the total variance. According to the second criterion (Kaiser's rule) only PCs with an eigenvalue greater than 1 are chosen. Finally, based on the third criterion PCs to the left of the Scree Plot "elbow" point are chosen. The environmental quality index (EQ) is calculated as a linear combination of the product of the selected PCs scores and relative variance percentages, as proposed by Musse et al. (2018) and Li & Weng (2007):

$$EQ_i = \sum_{j=1}^{n} PC_{j\_score} * v_j \tag{2}$$

Where EQ_i is the environmental quality index of the *i*-th shelter area, j is the number of selected PCs, PC_{j_score} is the score of the *j*-th PC and v_j is the variance percentage explained by the *j*-th component. EQ values are standardised using the following formula (Zhong et al., 2020):

$$EQi_{stand} = \frac{EQi - min\{EQ\}}{max\{EQ\} - min\{EQ\}} \qquad \text{i } (1, 2, \ldots, 9) \tag{3}$$

Where EQi_{stand} is the standardized environmental quality index of the *i*-th shelter area. The EQi_{stand} values are finally classified into five classes, referring to ranking used by the DGNB, BREEAM and GBC-LEED certification systems: bad ($EQi_{stand} \leq 0.35$), poor ($0.35 < EQi_{stand} \leq 0.55$), fair ($0.55 < EQi_{stand} \leq 0.65$), good ($0.65 < EQi_{stand} \leq 0.80$), and very good ($0.80 < EQi_{stand} \leq 1$).

4. Results and discussion

4.1 Parameters analysis

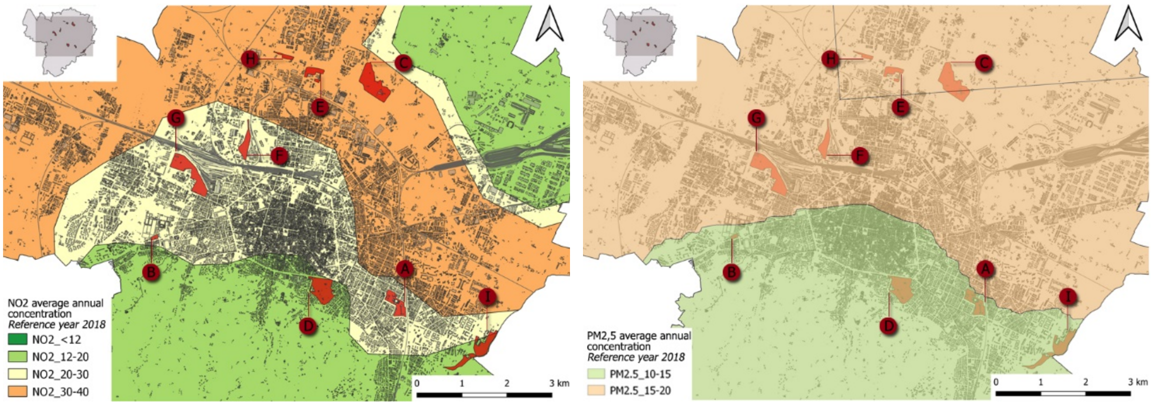
Air quality

The information necessary for the assessment of air quality refers to 2018, due to the data made available by Arpae (Regional agency of prevention, environment, and energy) of Emilia-Romagna. Normative references (Tab. 1) require air quality to be assessed based on the concentration levels of 11 pollutants: NO_2, NOx, PM^{10}, $PM^{2.5}$, Pb, B_6H_6, CO, As, Cd, Ni, C_20H_{12}. However, NOx concentration values are only available for three shelter areas, B6H6 and CO concentration values are not available for any area, and concentration values concerning Pb, As, Cd, Ni and C_20H_{12} are only available for Giardini Margherita area, within which a monitoring station is installed. Due to the lack of data, only three indicators have been included in the assessment (Tab.3). Fig.3 synthetizes data concerning NO_2 and $PM^{2.5}$ atmospheric concentration. Data retrieved from monitoring stations have been referred to areas of representativeness defined according to the Technical Report *Criteria for EUROAIRNET* (Larssen, Sluyter & Helmis, 1999) based on the type of monitoring station.
Concentration values are compared to related limit or target values and threshold ones (Tab.3).
From the comparison it can be noted that: (i) NO_2 concentration is below the lower assessment threshold only in one of the nine areas (Giardini Margherita); in the others it is between the lower and upper assessment threshold or close to the limit value (Parco Nord, Via di Corticella - Caserme Rosse, Via dell'Arcoveggio); (ii) concentration values of PM^{10} are higher than the upper assessment threshold in all the areas; (iii) in no area PM2.5 concentration is below the lower assessment threshold; it is between the lower and upper assessment threshold in three areas (Giardini Lunetta Gamberini, Antistadio, Giardini Margherita) and between the upper assessment threshold and the limit value in all the others.

Shelter area	Pollutant	Concentration value[4] ($\mu g/m^3$)	Limit value[4] ($\mu g/m^3$)	Upper assessment threshold[4] ($\mu g/m^3$)	Lower assessment threshold[4] ($\mu g/m^3$)
Giardino Lunetta Gamberini	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12
Antistadio	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12
Parco Nord	NO_2	30-40	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Giardini Margherita	NO_2	12-20	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12
Via di Corticella – Caserme Rosse	NO_2	30-40	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Via dè Carracci – Parco di Villa Angeletti	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Via del Chiù	NO_2	20-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Via dell'Arcoveggio	NO_2	30-40	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	15-20	25	17	12
Parco dei Cedri	NO_2	12-30	40	32	26
	PM^{10}	20-30	40	28	20
	$PM^{2.5}$	10-15	25	17	12

Tab.3 Pollutant atmospheric concentration values in shelter areas

[4] Annual mean, that is 90 % of the one hour values or (if not available) 24-hour values over the year.



(a) (b)

Fig.3 (a) NO_2 and (b) $PM^{2.5}$ atmospheric concentration

Water quality

Water quality in shelter areas is assessed by analysing the ecological and chemical status of the surface water bodies, and the quantitative and chemical status of the groundwater bodies.

The definition of the ecological and chemical status of water bodies belonging to a specific river basin allows to evaluate the achievement of the quality objectives established by Directive 2000/60/EC (Arpae of Emilia-Romagna, 2019). In Italy, DM 260/2010 establishes the technical criteria for the classification of the ecological and chemical status of surface waters. The ecological status of a water body is classified according to the lowest class resulting from monitoring data relating to the physicochemical supporting, chemical and biological elements. In Bologna metropolitan area 30 pickup stations were monitored in 2018, all of these located in Reno Basin. Data concerning monitoring stations of interest for shelter areas[5] were collected from the Arpa of Emilia-Romagna (Arpae) website. The other useful data have been found by the Water Management Plan contents retrieved from minERva web portal.

Arpae assesses following parameters to define the ecological status:

- the three-year mean value of the LIM_{eco} descriptor (*Pollution Level by Macrodescriptors for Ecological Status*), defined according to the concentrations of Ammoniacal Nitrogen, Nitric Nitrogen, Total Phosphorus and Dissolved Oxygen (100 - % O_2 saturation);
- the status assigned to the specific pollutants contained in Table 1/B of Annex 1 to DM 260/2010, which contains substances not included in the list of priorities and for which annual average quality standards (SQA-MA) are defined (Arpae of Emilia-Romagna, 2019). Only substances for which there is evidence of significant emissions in the water bodies are monitored;
- the resulting state of individual biological elements (benthic macroinvertebrates, benthic diatoms, and river macrophytes).

The DM 260/2010 provides for the monitoring of priority substances (P), priority hazardous substances (PP) and substances included in the list of priorities (E) for the definition of the chemical status of surface water. The environmental quality standards are defined both in terms of Average Annual Value (SQA-MA) and Maximum Allowable Concentration (SQA-CMA) in Table 1/a of Annex 1 to the DM. Section A.4.6.3 of the DM represents the reference for the attribution of chemical status. Only substances which have been shown by pressure and impact analysis to be emitted, discharged, released, or leaked in the catchment area or sub-catchment area have been monitored (Arpae, 2019).

[5] Monitoring stations related to for surface water bodies in whose sub-basin at least one of the shelter areas falls have been analysed. Surface water, indeed, is taken for civil and irrigation purposes.

Tab. 5 summarizes data concerning surface water bodies related to water catchments in which at least one shelter area falls (Fig. 4a). The three-year reference period is 2014-2016, as at the time of writing data for the 2017-2019 three-year period have not yet been published (only the partial provisional states referring to the single year are available). Chemical status is good for all surface water bodies analysed, while ecological status is sufficient only for two ones (in whose sub-basins the areas of shelter of Via del Chiù, Antistadio and Parco dei Cedri fall), and poor for all the others. Verbal evaluations were converted to numerical values according to the correspondences in Tab. 4.

Ecological status classes	Corresponding numeric value
high	4
good	3
moderate	2
poor	1
bad	0
Chemical status classes	**Corresponding numeric value**
good	3
falling to achieve good	0

Tab.4 Correspondences used for the numeric conversion of surface water ecological and chemical status classes

Water body ID	Reference station by grouping	Ecological status	Corresponding numerical value	Chemical status	Corresponding numerical value	Related shelter area
0600000000009 ER	06002100	Moderate	2	Good	3	Via del Chiù Antistadio
0616000000001 ER	06002700	Poor	1	Good	3	Via dè Carracci – Parco di Villa Angeletti Via dell'Arcoveggio Via di Corticella-Caserme rosse
0616000000002 ER	06002700	Poor	1	Good	3	
0617000000001 ER	06002800	Poor	1	Good	3	Parco Nord Giardini Margherita Giardino Lunetta Gamberini
0620020000007 ER	06003200	Moderate	2	Good	3	Parco dei Cedri

Tab.5 Surface water bodies ecological and chemical status and corresponding numerical values

With regards to groundwater bodies, European Directive 2000/60/EC provides for their monitoring through two networks, one for the definition of quantitative status and the other for the definition of chemical status. In the municipality of Bologna there are 25 groundwater status monitoring stations, distributed among the various types of aquifer identified in accordance with D.Lgs. 30/2009.

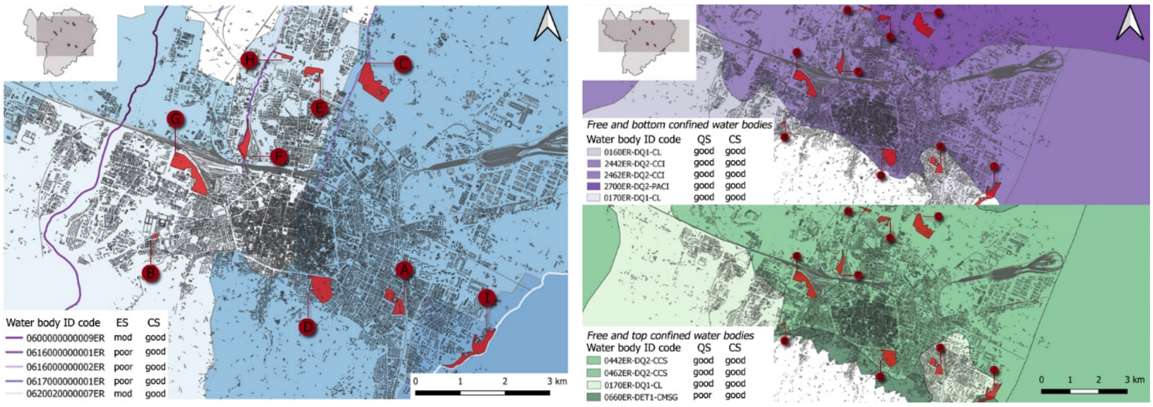
Quantitative status monitoring is carried out to provide a reliable estimate of available water resources and to assess their trend over the time, in order to verify whether the variability of charging and the sampling regime are sustainable over the long term.

Chemical status monitoring is articulated in surveillance monitoring, which is carried out according to previous knowledge of chemical status, and of vulnerability and renewal rate of each water body, and in the operational one, which is programmed for groundwater bodies that risk not reaching good status. As for surface waters, Arpae provides data on the quantitative and chemical status of groundwater with reference to the three-year period 2014-2016 (Tab. 6 and Fig. 4b). The conversion of the verbal evaluation into numerical value was carried out according to the correspondences in Tab. 4. An average weighted on the territorial extent associate to each groundwater body has been calculated for areas associated with more than one groundwater body. The status of groundwater is assessed as good for all examined groundwater bodies except for the mountain conoid that partially affects the area of Parco dei Cedri, whose quantitative status is assessed as poor.

Water body ID	Water body name	Monitoring station ID[6]	Quantitative status	Corresponding numerical value	Chemical status	Corresponding numerical value	Related shelter area
0160ER-DQ1-CL	Reno-Lavino conoid - free	SQ: BOE9-00 SC: BO20-00 BO47-01 BOE9-01 BOF0-00 BOH5-00 BOH6-00	Good	3	Good	3	Antistadio
2442ER-DQ2-CCI	Reno-Lavino conoid – bottom confined	SQ: BO20-01 BO30-00 SC: BO20-01 BO30-01	Good	3	Good	3	Via del Chiù Via dè Carracci – Parco di Villa Angeletti Via dell'Arcoveggio
2462ER-DQ2-CCI	Savena conoid – bottom confined	SQ: BO50-00 BO50-01 BO50-02 SC: BO50-02 BOH3-00	Good	3	Good	3	Via dell'Arcoveggio Giardini Margherita Parco dei Cedri
2700ER-DQ2-PACI	Alluvional Plain – bottom confined	SQ: BO78-01	Good	3	Good	3	Parco Nord Via di Corticella-Caserme rosse Via dell'Arcoveggio
0170ER-DQ1-CL	Savena conoid - free	SC: BO52-01	Good	3	Good	3	Giardino Lunetta Gamberini Parco dei Cedri
0442ER-DQ2-CCS	Reno-Lavino conoid – top confined	SQ: BOF8-00 SC: BO17-01	Good	3	Good	3	Via del Chiù Via dè Carracci – Parco di Villa Angeletti Via dell'Arcoveggio
0462ER-DQ2-CCS	Savena conoid – top confined	SQ: BO32-00 SC: BO32-00 BOA3-00 BOH4-00	Good	3	Good	3	Via dell'Arcoveggio Via di Corticella-Caserme rosse Parco Nord Giardini Margherita
0170ER-DQ1-CL	Savena conoid - free	SC: BO52-01	Good	3	Good	3	Giardino Lunetta Gamberini Parco dei Cedri
0660ER-DET1-CMSG	Mountain conoid	[-]	Poor	1	Good	3	Parco dei Cedri

Tab.6 Groundwater bodies quantitative and chemical status and corresponding numerical values

6 Only monitoring stations located in the municipality of Bologna are listed in the Table. SQ: quantitative status monitoring stations. SC: chemical status monitoring stations.



(a) (b)

Fig.4 (a) surface water bodies status and relate river basins; (b) groundwater bodies status

Light pollution

The use of unscreened lighting structures that direct part of the luminous flux directly to the sky is the main cause of light pollution. For this reason, standards and regulations to limit the phenomenon of light dispersion with regards to public lighting have been developed in recent years. Several studies have also shown that prolonged exposure to artificial night light inhibits melatonin production and this may cause sleep disorders and cancer (Garcia-Saenz et al., 2020; Kogevinas et al., 2018; Aubè et al., 2013).

Light pollution may therefore damage human health.

Several Italian regions have enacted laws aimed at reducing light pollution in recent years, and have introduced a special urban planning tool called Town Development Plan for Municipal Lighting (PRIC). It aims to assess the consistency and maintenance status of public lighting systems and to provide for the consequent adjustment, replacement and increase of existing light points (Santonico, 2011)[7].

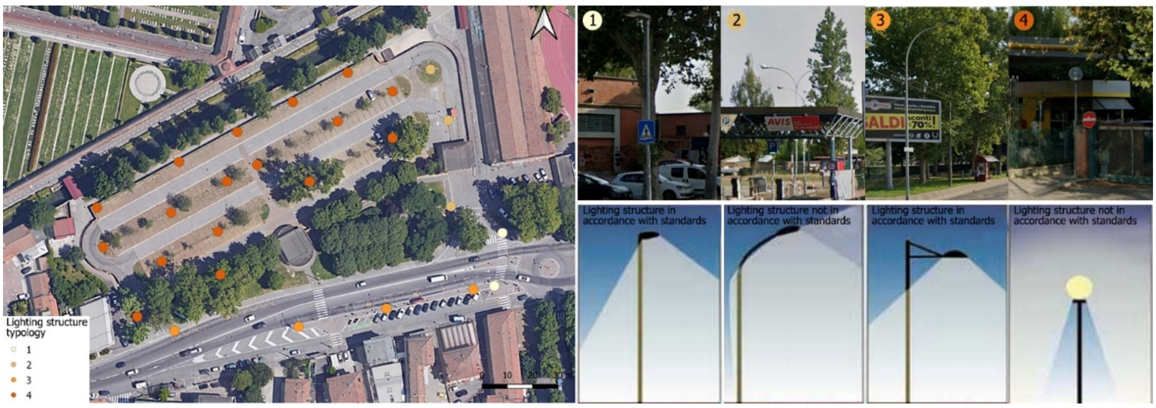


Fig.5 Lighting structures localization and typology in the Antistadio area (lighting structures reference images source: www.cielobuio.org)

Regulations provide for the emission values directed upwards allowed. In most cases, no light intensity greater than 0 cd/klm (candles per kilolumen) is allowed for angles greater than 90° (horizontal plane).

The Model Lighting Ordinance (MLO) (Ida & IES, 2011) also sets maximum luminous intensity values beyond the horizontal plane. The Ordinance provides for a lighting zones classification in five categories depending on

[7] Regions that do not have their own regulations refer to UNI 10819:1999, which prescribes the permitted percentages of average upward luminous flux.

their use. Since shelter areas are spaces used for people stay, these belong to LZ-2 class[8]. Table C-2 of the Users' Guide of the MLO considers a maximum percentage of light emission allowed above the horizontal plane equal to 0% in this zone.
The number and type of lighting structures located within each area and along its perimeter roads (Tab. 7) have been identified through the Google Earth Pro software in order to obtain the light pollution indicator. Only four shelter areas are characterized by a percentage of lighting structures according to standards higher than 50%, as they are partially adjacent to some of the roads object of the relamping operation started by the City Council in 2018. Fig. 5 shows as example the analyses carried out for Antistadio area.

Shelter area	**No. of lighting structures** Ls_{tot}	**No. of lighting structures according to standards** $Ls_{0\%}$	**Percentage deviation** $Ls_{0\%}/Ls_{tot}$ **(%)**
Giardino Lunetta Gamberini	84	36	42.85
Antistadio	26	6	23.08
Parco Nord	131	22	16.79
Giardini Margherita	141	60	20.10
Via di Corticella – Caserme Rosse	73	51	69.86
Via dè Carracci – Parco di Villa Angeletti	92	77	83.69
Via del Chiù	87	68	78.16
Via dell’Arcoveggio	24	20	83.33
Parco dei Cedri	116	36	31.03

Tab.7 Light pollution assessment in shelter areas

Noise pollution

Noise pollution is “the introduction of a level of noise into the environment which causes disturbance to rest and human activities, danger to human health, deterioration of ecosystems, property, monuments, and of the environment or that interferes with the normal functions of the environment” (art. 2 of L. 447/1995). Transport infrastructure are the mainly noise pollution source in the cities. High noise levels may cause psycho-physical illnesses even serious (Gargiulo & Romano, 2011). Within the European Community, data on noise pollution levels should be collected and presented according to comparable criteria (Directive 2002/49/EC). This requires the use of shared descriptors and methods to align acoustic mapping. With this aim, Directive introduces two indicators: the day-evening-night noise level (L_{den}) and the night noise level (L_{night}). With respect to these parameters, the Italian Legislator has not yet issued decrees that allow the conversion of the limit values identified by national legislation (LVA for airport noise, LA_{eq} day and LA_{eq} night for the other infrastructure) into the corresponding limit values of L_{den} and L_{night}. Nevertheless, Emilia-Romagna Region has introduced its own methodology to carry out this conversion through the Guidelines for the drafting of strategic noise maps. In this study reference was therefore made to the L_{den} and L_{night} indicators as they were in line with the latest European noise regulations.
L_{den} and L_{night} levels related to shelter areas were extracted from the strategic noise map provided by the Emilia-Romagna Region in 2017 as part of the cognitive framework of the Action Plan of the Agglomeration of

[8] Class LZ-2 includes areas of human activity where residents and users vision is adapted to moderate light levels. Lighting is generally used for safety and practical reasons but is not necessarily uniform and continuous. LZ-2 includes multi-family residential uses, schools, churches, hospitals, commercial and/or business areas, neighbourhoods serving recreational and playing fields and/or mixed-use development with a predominance of residential uses.

Bologna[9]. The mean value of the L_{den} and L_{night} descriptors has been calculated for each area, weighed against the extent of the surfaces characterised by each noise level (Tab. 8). Fig. 6 shows as example the levels of L_{den} and L_{night} relative to the Antistadio area.

(a) (b)

Fig.6 Strategic noise map concerning (a) L_{den} levels and (b) L_{night} levels in Antistadio area

Shelter area	L_{den_mean} dB(A)	L_{night_mean} dB(A)
Giardino Lunetta Gamberini	58.9	46.9
Antistadio	69.2	60.7
Parco Nord	73.4	65.4
Giardini Margherita	62.3	47.7
Via di Corticella – Caserme Rosse	72.8	64.8
Via dè Carracci – Parco di Villa Angeletti	58.7	50.7
Via del Chiù	61.3	54.0
Via dell'Arcoveggio	82.5	75.2
Parco dei Cedri	66.3	59.4

Tab.8 L_{den} and L_{night} mean values in shelter areas

Shelter areas can be considered as mainly residential areas, due to their use in emergency phase. For this land use class current national legislation provides noise emission limits corresponding to 52.7 dB(A) for L_{den} and 42.0 dB(A) for L_{night}. As showed by Tab. 8 these limits are exceeded in all the analysed areas. In no shelter area is therefore guaranteed adequate acoustic comfort.

Heat island effect

Urban heat island effect (UHI) is the phenomenon that determines a microclimate warmer within urban areas than the surrounding rural areas. High temperatures have several negative consequences including the increase in mortality rate (Santamouris, 2016). UHI is mainly caused by high incident radiation and by the high absorption coefficient of materials used for horizontal exterior coatings and roofing.
Each surface, indeed, has a more or less high capacity to absorb heat. This capacity is measured by the coefficient of solar reflection (Albedo): when its value increases (maximum to 1) the amount of heat reflected by the surfaces increases; conversely, low Albedo values characterize surfaces able to absorb a large amount of solar energy (Tab. 9).

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[9] Strategic noise map is obtained by summing the contributions deriving from road, railway, and airport noise source. The map is different from the noise classification of the municipal territory, which represents the noise limit values to be respected in the different acoustic zones.

In this study, heat island effect is assessed by analysing the solar reflection capacity of horizontal surfaces. Shelter areas have been divided into homogeneous sub-areas and the relative Albedo has been assigned to them. A mean Albedo value was then calculated for each shelter area as the average of the solar reflection coefficients weighed with respect to the extent of related surfaces (Tab. 10). Fig. 7 shows as example the horizontal surfaces identified in Antistadio and in Giardini Margherita areas and related Albedo.

Surface	Coefficient of solar reflection (Albedo)[10]
Unpaved road	0.04
Water	0.07
Asphalt	0.1
Concrete	0.2
Dark roof	0.25
Light roof	0.35
Grass	1

Tab.9 Coefficients of solar reflection (Albedo) of several surfaces

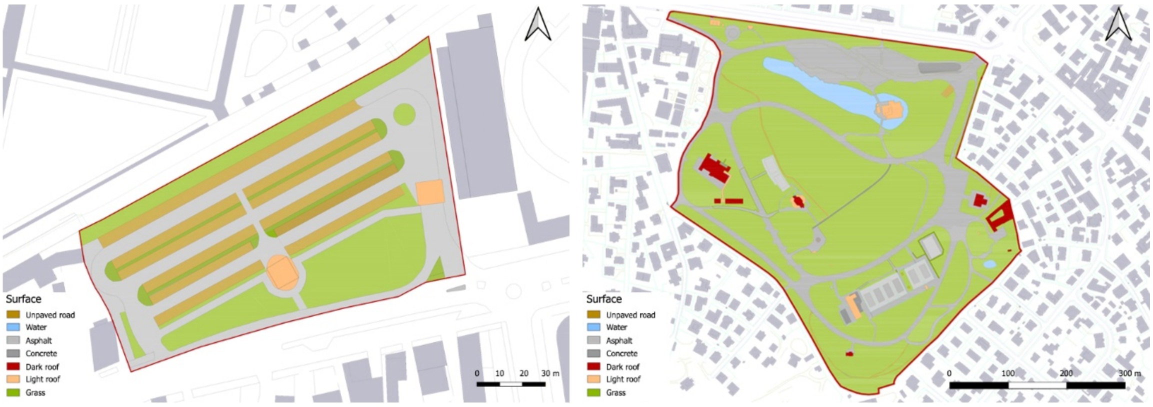

Fig.7 Homogeneous sub-zones and related Albedo in (a) Antistadio and (b) Giardini Margherita areas

Albedo mean value is rather high in the examined areas, since they are mostly public parks and so characterized by a large presence of grass, which corresponds to the maximum value of the coefficient of reflection. Lower Albedo mean value is that of Antistadio area because it is used as a parking space in non-emergency conditions and consequently it is mainly characterized by asphalt surfaces. The microclimate of this area may therefore be uncomfortable in the summer season.

4.2 Final output: environmental quality index

As explained in Section 3.2, the overall environmental quality index of shelter areas is calculated by using PCA. Three variables ($PM10_{conc}$, CS_SWB, and CS_GWB) were excluded from the PCA as they have equal value in all nine areas and therefore there is no variability in data distribution (zero standard deviation). Pearson's correlation matrix among the nine variables with non-zero standard deviation was then calculated (Tab.11). The PCA results are shown in Tab.12, Tab.13 and Fig.8.

[10] Albedo characteristic values in the Table are those used by the ITACA Protocol at Urban Scale for the evaluation of the indicator 7,02.3. Albedo of water surfaces is provided by UNI 8477.

Shelter area	Homogeneous sub-zone	Albedo of homogeneous sub-zone	Homogeneous sub-zone surface (m^2)	Homogeneous sub-zone surface as percentage on the shelter area surface (%)	Alb_{mean} of shelter area
Giardino Lunetta Gamberini	Unpaved road	0.04	20,046.07	12.41	0.80
	Water	0.07	[-]	0	
	Asphalt	0.1	23,050.83	14.27	
	Concrete	0.2	1,632.39	1.01	
	Dark roof	0.25	6,501.14	4.01	
	Light roof	0.35	8,525.23	5.28	
	Grass	1	101,822.40	63.02	
Antistadio	Unpaved road	0.04	3,131.62	21.36	0.55
	Water	0.07	[-]	0	
	Asphalt	0.1	7,033.63	47.97	
	Concrete	0.2	[-]	0	
	Dark roof	0.25	[-]	0	
	Light roof	0.35	286.65	1.96	
	Grass	1	4,210.18	28.71	
Parco Nord	Unpaved road	0.04	4,931.42	1.73	0.76
	Water	0.07	[-]	0	
	Asphalt	0.1	8,302.23	2.92	
	Concrete	0.2	71,268.96	25.02	
	Dark roof	0.25	908.04	0.32	
	Light roof	0.35	5,722.07	2.01	
	Grass	1	193,685.54	68.00	
Giardini Margherita	Unpaved road	0.04	1,633.39	0.69	0.78
	Water	0.07	7,712.67	3.27	
	Asphalt	0.1	6,076.06	2.58	
	Concrete	0.2	53,595.25	22.72	
	Dark roof	0.25	3,270.16	1.39	
	Light roof	0.35	2,316.39	0.98	
	Grass	1	161,296.15	68.37	
Via di Corticella – Caserme Rosse	Unpaved road	0.04	3,529.53	2.68	0.73
	Water	0.07	[-]	0	
	Asphalt	0.1	14,908.85	11.34	
	Concrete	0.2	16,812.45	12.79	
	Dark roof	0.25	8,469.30	6.44	
	Light roof	0.35	3,341.15	2.54	
	Grass	1	84,430.27	64.21	
Via dè Carracci – Parco di Villa Angeletti	Unpaved road	0.04	7,132.60	6.50	0.96
	Water	0.07	6,170.49	5.62	
	Asphalt	0.1	[-]	0	
	Concrete	0.2	4,818.83	4.39	
	Dark roof	0.25	19.55	0.02	
	Light roof	0.35	18.90	0.02	
	Grass	1	91,578.30	83.45	
Via del Chiù	Unpaved road	0.04	9,128.42	2.64	0.88
	Water	0.07	2,526.17	0.73	
	Asphalt	0.1	13,251.45	3.84	
	Concrete	0.2	30,014.20	8.69	
	Dark roof	0.25	3,451.74	1.00	
	Light roof	0.35	6,582.51	1.90	
	Grass	1	280,551.39	81.2	
Via dell'Arcoveggio	Unpaved road	0.04	[-]	0	0.98
	Water	0.07	[-]	0	
	Asphalt	0.1	586.60	2.17	
	Concrete	0.2	55.82	0.21	
	Dark roof	0.25	[-]	0	
	Light roof	0.35	17.07	0.06	
	Grass	1	26,397.32	97.56	
Parco dei Cedri	Unpaved road	0.04	8,184.53	3.45	0.87
	Water	0.07	10,037.46	4.22	
	Asphalt	0.1	13,439.96	5.66	
	Concrete	0.2	12,530.06	5.27	
	Dark roof	0.25	1,638.41	0.69	
	Light roof	0.35	5,676.86	2.39	
	Grass	1	186,116.6	78.32	

Tab.10 Mean values of coefficient of solar reflection (Albedo) of shelter areas

	NO_{2conc}	$PM^{2.5}_{conc}$	ES_SWB	QS_GWB	$Ls_{0\%}/Ls_{tot}$	L_{den_mean}	L_{night_mean}	Alb_{mean}
$NO2_{conc}$	1.000							
$PM2.5_{conc}$	0.437	1.000						
ES_SWB	-0.358	-0.158	1.000					
QS_GWB	0.327	0.316	-0.500	1.000				
$Ls_{0\%}/Ls_{tot}$	0.353	0.956	-0.151	0.247	1.000			
L_{den_mean}	0.737	0.185	-0.157	0.045	0.072	1.000		
L_{night_mean}	0.781	0.290	-0.022	-0.044	0.183	0.968	1.000	
Alb_{mean}	0.055	0.545	-0.261	-0.165	0.652	-0.023	0.044	1.000

Tab.11 Pearson's correlation matrix among variables used in PCA

	Eigenvalue	% of variance	Cumulative %
λ1	3.319	41.49	41.49
λ2	2.065	25.81	67.30
λ3	1.433	17.91	85.21
λ4	0.808	10.10	95.31
λ5	0.212	2.65	97.96
λ6	0.132	1.65	99.61
λ7	0.003	0.04	99.65
λ8	0.028	0.35	100.00
Total	8.000	100.00	

Tab.12 Eigenvalues of Pearson's correlation matrix and related percentage of variance

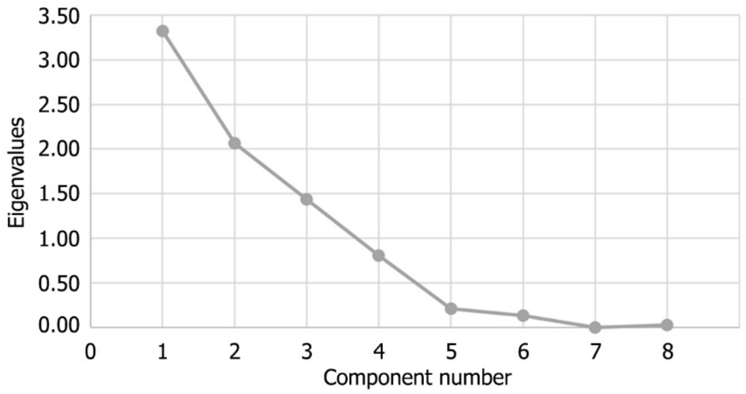

Fig.8 Eigenvalues Scree Plot

	PC1	PC2	PC3
NO_{2conc}	-0.463	-0.260	-0.116
$PM^{2.5}_{conc}$	-0.427	0.355	0.115
ES_SWB	0.225	-0.106	0.558
QS_GWB	-0.197	0.106	-0.690
$Ls_{0\%}/Ls_{tot}$	-0.392	0.434	0.158
L_{den_mean}	-0.378	-0.469	0.099
L_{night_mean}	-0.401	-0.430	0.229
Alb_{mean}	-0.237	0.436	0.314
Eigenvalue (λ)	3.319	2.065	1.433
% of variance	41.49	25.81	17.91

Tab.13 Loadings of maintained PCs following the use of Heuristic criteria

According to the first and the second Heuristic criterion the first three PCs should be maintained, as they represent more than 80% of the overall variance, and the three related eigenvalues are greater than 1 (Kaiser's rule). According to the third Heuristic criterion the first five components should be maintained, as in the Scree Plot there is a sharp change of slope ("elbow" of the curve) at the fifth eigenvalue. Since two of three Heuristic criteria give the same result, it was decided to use three PCs (Tab. 13). PC1 considers mainly atmospheric quality, as it has good negative correlations (loadings) with $NO2_{conc}$ (-0,46) and $PM2.5_{conc}$ (-0,43).

PC2 considers mainly comfort levels offered by the areas, as it has good positive correlations with $Ls_{0\%}/Ls_{tot}$ (0,43) and Alb_{mean} (0,44), and good negative correlations with L_{den_mean} (-0,47) and L_{night_mean} (-0,43).

Finally, PC3 represents mainly surface and ground waters conditions, as it has higher correlations with ES_SWB (0,56) and QS_GWB (-0,69).

The environmental quality index (EQ) of the nine shelter areas was obtained by combining the scores of the PCs with their variance percentages, by using equation (2) (Tab. 14). The EQ values have been standardised using equation (3) and subsequently classified according to the ranges described in Section 3.2 (Fig. 9).

	PC1	**PC2**	**PC3**	**EQ_{stand}**
Giardino Lunetta Gamberini	-75.352	-30.695	20.609	0.90
Antistadio	-76.737	-50.263	22.134	0.61
Parco Nord	-82.650	-59.387	20.977	0.34
Giardini Margherita	-63.857	-40.182	18.565	1.00
Via di Corticella - Caserme Rosse	-105.132	-34.041	29.745	0.28
Via dè Carracci - Parco di Villa Angeletti	-94.996	-12.657	28.547	0.79
Via del Chiù	-94.889	-17.838	29.216	0.72
Via dell'Arcoveggio	-118.311	-37.107	35.291	0.00
Parco dei Cedri	-76.068	-43.924	24.751	0.74

Tab.14 PCs scores and EQ_{stand} values for shelter areas

As shown by Fig. 9, The EQ_{stand} of three shelter areas (Via dell'Arcoveggio, Via di Corticella - Caserme Rosse, Parco Nord) falls into the bad class. According to the proposed methodology, this means that these sites do not guarantee adequate comfort and safety conditions for human health. It is interesting to note that the three areas are located close to each other. They are located in the northern zone of Bologna, where the worst environmental quality conditions are recorded compared to the rest of the city. Another aspect to consider is that all three areas are bordered by the highway, which is a significant noise source both day and night. Results thus show that shelter areas identified by the Emergency Plan to accommodate the population living in the northern of the city would not be able to guarantee conditions suitable for the people stay, especially with regard to air and noise pollution.

5. Conclusions

The experimentation of the proposed methodology in the Municipality of Bologna confirmed the thesis supported by this study. Results demonstrate the usefulness of providing planners and operators of the Civil Protection an environmental zoning of the municipal territory, in order to facilitate the identification of the areas most suitable for the shelter and the stay of populations displaced due to the occurrence of disasters. Experimentation final output, indeed, highlighted that three of the nine shelter areas identified by Emergency Plan are not able to ensure environmental condition suitable for the more or less prolonged stay of people.

This is caused mainly by the excessive proximity to the highway, which results in high levels of noise both day and night, and in the increase in the concentration of air pollutants. The fact that all three areas with the worst

EQ are located in the northern part of the city constitutes a disadvantage for the population living in this area, because in emergency case it would be hosted in places with characteristics much worse than those designated to accommodate citizens of Bologna central area.

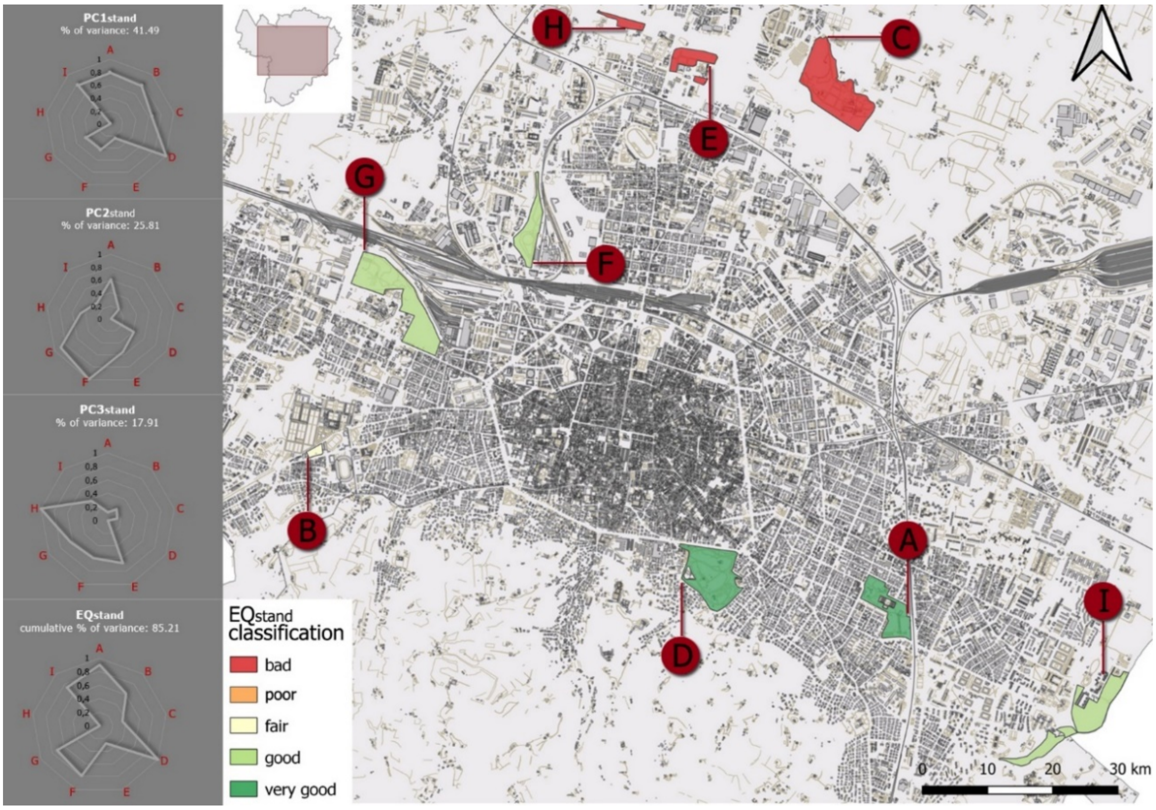

Fig.9 Graphs of PCs standardized scores and of EQ_{stand}; shelter areas classification based on EQ_{stand} values

This aspect should be considered by the future emergency planning. The model proposed in this study could be replicated in other municipalities, allowing a more accurate identification of the shelter areas in the planning phase but also the evaluation of those already identified by current Emergency Plan.

Neverthless, two issues need to be highlighted. First, in this study the classification of the shelter areas is based on a comparison of their EQ_{stand}. This technique shows its potential when there is a set of alternatives to choose from, in this case when the identification of sites with better and worse environmental conditions allows to decide where to locate shelter areas. However, it is useful that future studies concern at defining a threshold value for environmental quality, in order to exclude from subsequent evaluations areas that do not reach sufficient EQ values to ensure adequate levels of environmental comfort.

Secondly, we are aware that environmental quality cannot be the only discriminating factor in the choice of the shelter areas. Accessibility and strategic location, as well as the absence of risks, are fundamental elements in this respect. Environmental assessment may seem to be of secondary importance in relation to them. Nevertheless, it should be considered that shelter areas often host evacuated citizens for much longer periods of time than planned ones. For this reason, it is necessary to think about new forms of relationship between the Emergency Plan and the territorial analysis, which ensure the involvement of all the components characterizing territory through a dynamic, cognitive, active, and continuously updated approach.

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Image sources

Fig.1: Authors' elaboration;

Fig.2: Authors' elaboration;

Fig.3: Authors' elaboration;

Fig.4: Authors' elaboration;

Fig.5: Authors' elaboration;

Fig.6: Authors' elaboration;

Fig.7: Authors' elaboration;

Fig.8: Authors' elaboration;

Fig.9: Authors' elaboration.

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Fostering holistic natural risk resilience in spatial planning

Earthquake events, cultural heritage and communities

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Abstract

Natural disasters lead to the destruction of (land/urban) scape values and cultural heritage, social and cultural ties, and directly impact spatial resources that appeal to spatial planning with a view to enhancing the current resilience and reducing future risks. The aim of this research is to build a framework of knowledge to integrate perspectives of natural risk resilience (natural risk, cultural heritage, communities, spatial resources, and spatial planning) tested on research cases in areas affected by earthquakes in Italy and Croatia. The Heritage Urbanism approach is applied by comparing the Central Italy disaster and trends in the Croatian capital of Zagreb, providing identity factors and evaluation criteria to assist in reading existing resilience models and building new models. Structures to interrelate aspects of (land/urban) scape resilience and models of natural risk resilience contribute to enhancing risk reduction and resilience in urban planning in high-risk situations. Achieving holistic natural risk resilience is possible when (land/urban) scape, cultural, identifying, social, spatial, planning, and economic resilience models are integrated such that they benefit from each other. Spatial planning responses to natural disasters that affect cultural and (land/urban) scape heritage and spatial resources must be planned in close interaction with local communities to improve preparedness and prevent destruction, damage, and loss of collective memory, tradition, and identity.

Keywords

(Land/Urban) scape values; Comprehensive renewal; Identity affirmation; Central Italy; City of Zagreb.

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1. Introduction

Natural disasters (earthquakes, landslides, floods, droughts, tornadoes, fires, etc.) cause immense losses in terms of human lives, goods, and property. Dealing with disasters is not just a question of destroyed buildings and assets. It involves the destruction or interruption of the ties, connections, and socio-cultural networks in affected communities, the loss or decline of genius loci, and the image of the (land/urban) scape and authenticity, leading to changes in cultural practices and traditions that directly impact the spatial dimension (Sargolini, 2017). It appeals to emergency management, spatial planning strategies, and legislation framework that addresses consequences with a view to reducing future risks and enhancing the current resilience. This research is conducted from the spatial planning perspective, focusing on the contribution of cultural heritage and communities in the course of disaster/risk reduction and natural risk resilience.

The tectonic Apennine-Adriatic-Dinaride region represents a consistent block, with the Apennines and Dinarides being thrust towards a common foreland, though diverging to the south (Ollier & Pain, 2009). The wider spatial context of the research covers active seismotectonic points of the Apennine and Dinaride mountain areas, with the Po and Pannonian plains as bounds towards Alps. The more focused spatial context regards the location of major earthquakes that have occurred in the 21st Century in Central Italy — Apennines — and in Zagreb, the capital of Croatia — Pannonian Basin (Ivančić et al., 2006).

The pace of urban development and the repercussions on the Earth's ecosystem cause global warming, increase risks from natural disasters (earthquakes, extreme weather events, COVID-19 pandemic) and present global problems that demand a paradigm shift in the approach to spatial planning. This paradigm shift is enhanced by the Council of Europe Landscape Convention (Council of Europe, 2000; Council of Europe, 2016), European Green Deal (European Commission, 2019), Agenda for Sustainable Development (United Nations, 2015), and conventions recognizing the value of tangible and intangible cultural heritage for society (Council of Europe, 2005; UNESCO, 1972, 2003, 2019; European Commission, 2018) in forming global long-term goals (Colucci, 2012; Kallaos et al., 2014). The post-disaster processes in Italy (Central Italy) and Croatia (Zagreb) reveal a focus on emergency post-disaster recovery, taking long-term goals as a background. Natural disasters, however, highlight current spatial, social and cultural problems as a reminder to aim for values that enable comprehensive progress. On the national and regional scales, strengthening and encouraging the relationships between spatial, social, and cultural models promotes sustainable development (Council of Europe, 2006) and comprehensive resilience in spatial planning. Inspiration for the research lies in the chance to exchange spatial, community, and cultural knowledge to revive what has been affected by natural disaster.

The research presumes that actions to respond to natural events that affect cultural and (land/urban) scape heritage must be integrated into spatial planning processes and planned in close interaction with local communities to prevent the destruction, damage, and loss of collective memory, tradition, and identity, and to promote social, spatial, and symbolic resilience. Spatial models, as the synthesis of what actually exists and to promote improvements for the future, tie the natural basis of the landscape to the principles of social recognition, especially those related to identity, cultural heritage, ways of life, and social customs or behaviour (Council of Europe, 2006).

The integration of disaster/risk-reduction strategies into the spatial planning process entails a need to simulate the future impacts of disasters, and the most appropriate level to do so is the local level, as stated by the Incheon Declaration (Sargolini, 2020; UNESCO, 2015). However, risk reduction is beyond the capacity of the local authorities because the spatial extent of risks goes far beyond local boundaries, and a multi-level, multi-stakeholder approach would be most effective. Therefore, the goal of the research is to build a framework of knowledge based on holistic links between natural risk preparedness, cultural and (land/urban) scape heritage values in disaster recovery, and comprehensive resilience enhancement concerning spatial planning. This approach is tested on cases of earthquake-affected areas in central Italy and the Croatian capital of Zagreb.

The research question is how and in what ways spatial planning can face risk by increasing resilience, along with the wider implications regarding spatial management.

Central Italy has gained valuable experience in dealing with disaster consequences after the series of major earthquakes in August and October 2016 and January 2017. This experience is compared to trends in disaster recovery in the Croatian capital, which is just beginning to recover from earthquakes in March and December 2020[1]. In the research, the Italian experience of the Central Italy 2016 earthquake and recovery trends from the Zagreb 2020 earthquake are analysed to draw attention to risks and resilience in spatial planning of the cultural and (land/urban) scape heritage and the prosperity of resilient communities with high risk exposure.

1.1 Exchange within the body of natural risk resilience knowledge

According to the UNISDR (United Nations Office for Disaster Risk Reduction), disasters occur when a community has to deal with a situation that exceeds the capacity of public and private entities to cope with it (UNISDR, 2009a). In particular, the UNISDR refers to disasters as "a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources". Disasters are often described in the literature as a result of: i) the level of exposure to a hazard; ii) specific conditions of vulnerability; and iii) insufficient capacity or measures to reduce or address potential adverse impacts. A disaster therefore affects a territory (Colucci, 2015; Molavi, 2018) in both economic and social terms (Esopi, 2018), with the extent of the damage determined by the type and severity of the disaster, as well as the vulnerability and resilience of the community and related governing bodies. According to the UNISDR, Disaster Risk Reduction (DRR) is a systematic approach to identifying, assessing, and reducing the risks of disasters following natural and non-natural disasters. It aims to reduce socioeconomic vulnerabilities to disasters and address environmental and other dangers that can trigger or can amplify them.

Knowledge regarding natural risk resilience and disaster-risk reduction is based on international conventions, declarations, and documents. Input from international guidelines and directives highlights the need for an inter- and transdisciplinary approach and a comprehensive course in natural risk reduction. An inclusive and holistic approach in achieving natural risk resilience sets the need to overlap/connect different aspects – natural and spatial resources, cultural heritage, community, and spatial planning. Exchanging and enriching different perspectives on natural risk resilience generate the new state of art (Hyogo Framework for Action 2005-2015; Sendai Framework for Disaster Risk Reduction 2015-2030; Making Cities Resilient: My City is getting ready! Campaign 2030).

2. The Heritage Urbanism approach applied

The research approach is based on Heritage Urbanism[2], which sets three methodological levels aiming to recognize/determine/define identity factors, evaluation criteria, and enhancement models (Obad Šćitaroci et al., 2019; Obad Šćitaroci & Bojanić Obad Šćitaroci, 2019). The Heritage Urbanism approach is applied in

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[1] Zagreb was hit by earthquakes magnitude 5.5 and 5.0 in March 2020 and again by a series of earthquakes in Petrinja in December 2020 with maximum magnitude 6.4 and epicenter 50 km from Zagreb. In this paper the Zagreb 2020 earthquake refers to the March earthquake, since the December earthquake occurred during paper review and the data regarding earthquake consequences are still unavailable. The Petrinja 2020 earthquakes made substantial destruction to already damaged city of Zagreb. The earthquake effects to both Zagreb and Petrinja area are still being determined and the process of recuperation is currently ongoing, therefore the tendencies of disaster recovery are explored in Zagreb case.

[2] Heritage urbanism is a term created and developed within a research project titled Urban and Spatial Models for the Revival and Enhancement of Cultural Heritage conducted at the Faculty of Architecture of the University of Zagreb. The project lasted five years, from 2014 to 2018, was funded by the Croatian Science Foundation and lead by prof. Mladen Obad Šćitaroci, PhD (Obad Šćitaroci et al., 2019; Obad Šćitaroci & Bojanić Obad Šćitaroci, 2019).

analysing and comparing case studies and assists in reading existing resilience models and shaping new models that integrate natural risk resilience into spatial planning.

The case studies are compared regarding the natural disaster process in two stages with two groups of case studies. Overview examples present the history and consequences of seismic activity in the wider spatial context of the Apennine-Adriatic-Dinaride region including the Po and Pannonian plains. The research cases focus on most relevant earthquakes occurring in the 21st Century in Italy (Central Italy 2016 earthquake) and Croatia (Zagreb 2020 earthquake) presenting the process and challenges of natural disaster events.

The holistic links to natural disaster resilience are achieved when all (land/urban) scape dimensions — spatial, social and cultural (Sopina & Bojanić Obad Šćitaroci, 2019) — are nurtured. The Heritage Urbanism approach is applied on three methodological levels:

- Distinctive factors in the natural disaster process arise from exchange between the (land/urban) scape dimensions and research goal, as natural risk, cultural heritage, communities, spatial resources, and spatial planning;
- Evaluation criteria are used to analyse and compare the case studies and are differentiated for overview examples and research cases. Overview examples are compared through evaluation criteria regarding available data on seismic activity consequences. Evaluation criteria for research cases analysis are confirmed from the overview examples and introduced in two ways: as three phases in the course of a natural disaster and as perspectives of natural risk resilience recognized in extended distinctive factors;
- Existing resilience models are read in (land/urban) scape resilience dimensions and interconnected to foster holistic natural risk resilience. The research proposes resilience enhancement models as a simplified representation of an interrelated structure to advance natural risk resilience.

The materials and information used to conduct the scientific research were limited due to restrictive COVID-19 measures and the shock of the recent earthquake in Zagreb[3]. Therefore, the materials used focus on online publications and cartographic and photographic materials, complemented by data collected in on-site surveys in Central Italy and Zagreb.

3. Case study analysis

3.1 Historical overview of the impact of seismic activity

The history of active tectonic sites in the Apennines-Po and the Dinarides-Panonian regions is presented as an overview of most relevant historical and contemporary seismic events regarding the impact and effects on the territory, communities, and cultural heritage. The overview examples (Tab.1) include five seismic events in Italy (Friuli 1976, Irpinia 1980, L'Aquila 2008, Emilia Romagna 2012, Central Italy 2016) and three of the strongest earthquake events in Croatia at the end of the 19th century (Montenegrin Littoral/Dubrovnik 1979, Zagreb 1880 and 2020) (Šimetin Šegović & Šimetin Šegović, 2020; The City of Zagreb, 2020).

The comparative table and information regard data available on the seismic events and the spatial, community, and heritage consequences. Overview earthquake events range from magnitude 5.0 to 7.0 on the Richter scale, with various epicentre locations causing continental and undersea earthquakes, affecting areas of up to 20,000 square kilometres, up to 1,240,000 inhabitants, and with up to 2,735 casualties. The areas impacted

[3] The research is conducted during the COVID-19 quarantines of high restrictive measures in both Italy and Croatia, and focused on data available in the given circumstances. The research was conducted during the first nine (9) months after the Zagreb Earthquake in March 2020, thus the Croatian team used information available at the time. During the paper review process Zagreb was striken by the Petrinja earthquake in December 2020, that made substantial damage to the city of Zagreb. The effects of Petrinja earthquake to Zagreb are not presented in the paper.

range from low-density areas with small settlements to high-density areas of municipal seats, regional centres, and capital cities, reflecting different degrees of damage to homes, the cultural heritage, and public buildings.

Earthquake	**Zagreb**	**Friuli**	**Montenegro Littoral/Dubrovnik**	**Irpinia/Basilicata**	**Abruzzo**	**Emilia Romagna**	**Central Italy**	**Zagreb**
Date	09/11/ 1880	06/05/ 1976	15/04/ 1979	23/11/ 1980	06/04/ 2009	20/05/ 2012 29/05/ 2012	24/08/2016 30/10/2016 18/01/2017	22/03/ 2020
Epicentre	Medvednica mountain	Gemona – Artgena	Montenegro Littoral Bar – Ulcinj	Teora	Roio Colle – Genzano	Finale Emilia – Mirandola	Accumoli – Castelsantangelo sul Nera – Norcia	Medvenica mountain
Magnitude	6.3	6.4	7.0	6.9	6.3	5.9	6.5	5.5; 5.0
Victims/Injured	2 / 29	965	136 / 1,700	2,735	308	27	303	1 / 27
Left without homes	/	45,000	100,000	280,000	65,000	15,000	40,000	1,000
Affected inhabitants	30,000	/	/	/	/	/	600,000	1,240,000
Affected area km²	2,500	5,500	20,000	17,000	3,565	2,700	8,000	2,250
Affected Municipalities	/	137	/	687	57	60	140	51
Territorial type	Capital city	Small mountain centres	Regional centres, UNESCO Sites	Small and medium centres – Naples	Small and medium centres	Small centres, valley farms	Small and medium centres	Capital city
Population and building density	Low density	Low density	Low to high density	Low to high density	Low to medium density	Low density	Low to medium density	
Destroyed or unusable homes	485	18,000	/	20,000	22,816	37.122 in total 37% usable 22% damaged 41% unusable	49,954	5,843
Damaged homes	1,273	75,000	60,000	80,000	11,337		30,392	18,157
Damaged cultural heritage	/	/	1,376 in Dubrovnik Littoral	/	1,366		945 (Churches*)	364 Cultural Religious
Damaged public buildings	/	/	/	/	1,029		1,405	513 Health Education

* other cultural heritage is counted under "homes" and "public buildings"

Tab.1 Overview of historical earthquake consequences in the Central Italy and the Republic of Croatia (selection)

A comparison of the overview examples indicates different disaster severity, effects, and consequences, that are expressed as earthquake impact factors (Jurukovski, 1997; Lomnitz & Winser, 2012; Choudhury et al., 2016; European Commission, 2018) – location and depth of the epicentre, local geological conditions[4], magnitude, population and building density, level of economic development, level of social and cultural development, communication, accessibility for rescue teams, time of day, time of year and climate, secondary effects. Different primary and secondary earthquake effects (Choudhury et al., 2016), as well as the short- and long-term consequences of earthquake impacts (Clemente & Salvati, 2017), confirm earthquake-disasters as a process (Mulargia et al., 2004).

The extended identity factors of the natural disaster process are related to the earthquake impact factors and are therefore confirmed as evaluation criteria for the research cases. The earthquake events in Central Italy (2016) and Zagreb (2020) were selected as the most representative seismic events occurring in the 21st Century in Italy and Croatia for further analysis of the research cases.

[4] The area of impact is influenced by the location and depth of the epicenter and the local geologic conditions. In the case of Montenegro Littoral 1979 Earthquake, the epicenter was located about 15 kilometers from the sea coast between Bar and Ulcinj, having the strongest impact along the coastal area, with a significantly less impact on the continental mountain area. In the cases of continental earthquake events, the area of impact is mostly radial from the epicenter location.

3.2 Research cases — analysis of approaches to natural disaster change and challenge through pre-shock, shock, and aftershock phase

Analysis of the research cases was conducted using evaluation criteria – three phases in the course of a natural disaster and perspectives on natural risk resilience (Table II and III)[5]. The course of an earthquake encompasses the three phases of:

- pre-shock, preceding earthquake as the stillness phase;
- shock of earthquake and action as an emergency phase;
- aftershock of reactions and dealing with effects of the earthquake as a recovery phase, exposing the natural disaster as a process.

Perspectives on natural risk resilience are recognized in extended identity factors of the course of the natural disaster:

- natural risk (natural disaster and area affected);
- cultural heritage (protected cultural heritage and (land/urban) scape heritage);
- communities (collective meanings and local community);
- spatial resources (professional initiatives and spatial management);
- spatial planning (spatial planning strategies and legal framework).

The description of each research case summarizes the processes and challenges of natural disasters and emphasizes each disaster phase regarding spatial planning strategies and natural risk resilience.

3.3 Central Italy 2016 Earthquake

In 2016, the Apennine area of the 4 regions of Central Italy (Lazio, Umbria, Abruzzo, and Marche) was hit by a series of seismic events (Tab.2). The sequence began on 24 August 2016 with a 5.9-magnitude earthquake that caused the death of 297 people and the total destruction of the town of Amatrice, near the epicentre, Accumoli, and Pescara del Tronto. On 26 and 30 October 2016, new violent shocks rocked the same area, affecting the Umbria and Marche regions in particular, which were already deeply affected by the 24 August earthquake. The 26 October event featured two strong events of magnitude 5.4 and 5.9, and on 30 October another strong shock led to new damage and collapsed buildings. Unlike the August event, no victims were reported this time, but tens of thousands of people were involved and the number of damaged and collapsed buildings was even higher (Sargolini et al., 2019).

On 18 January 2017, four earthquakes of magnitude greater than 5 hit the Lazio and Abruzzo regions again. In this case, the event overlapped with an exceptional wave of bad weather and snow that affected the Abruzzo, Lazio, Marche, and Umbria regions and beyond. This multi-hazard caused an avalanche on the Gran Sasso d'Italia massif, hitting and destroying the four-star Hotel Rigopiano in Farindola, Abruzzo, with 29 deaths and 11 people injured, making it the deadliest avalanche in Italy since the White Friday avalanches in 1916 and the deadliest in Europe since the Galtür avalanche in 1999.

The Civil Protection Department coordinated the Central Italy earthquake emergency. Dicomac – Command and Control Directorate, established in Rieti after the Civil Protection ordinance of 26 August, managed the first emergency phase, focusing mainly on assisting the population (contributions for "independent accommodation", emergency housing solutions); recognizing damage to housing (Fast and Aedes reports), the artistic and cultural heritage, and public buildings; collecting and transporting rubble; and supporting livestock activities.

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[5] Tables II and III that research perspectives on natural risk resilience of the Central Italy 2016 Earthquake and Zagreb 2020 Earthquake represent the choice of resilience dimensions that are focused on achieving research goals, and represent the information quantity that enables the implementation of the research.

Perspectives on natural risk resilience of Central Italy 2016	**Pre-shock** Preceding earthquake Stillness phase	**Shock** Earthquake force and action Emergency phase	**Aftershock** Earthquake reactions and effects Recovery phase
Natural disaster	Umbria-Marche 1997: M 6.0 L'Aquila 2009	24 August 2016: M 6.0; 5.3 26 October 2016: M 4.4; 5.9 30 October 2016: M 6.5 18 January 2017: M 5.1; 5.5; 5.4; 5.0	Approximately 65,500 aftershocks recorded from 24 August 2016 to 28 April 2017 (3500 with magnitude equal to or greater than 2.5)
Area affected	Umbria-Marche 1997 L'Aquila 2009	4 regions, 10 provinces 8,000 km^2 Abruzzo 103,483, Lazio 72,798, Marche 348,473, Umbria 57,505 inhabitants	Extraordinary Commissioner and Regional Special Offices for Reconstruction – management and approval of reconstruction projects
Protected cultural heritage	Real estate and property Cultural-historical units Protected and preventively protected (national parks, natural reserves, N2K network)	Most severe damage to historical settlements and buildings	Implementing heritage enhancement projects in relation to the context An effective conservation model is not defined
Urbanscape heritage	Heritage uniformity Protected small settlements, hamlets, and individual buildings	New emergency settlements in contrast to old ones New urban landscape and new territorial organization	Focus on historical urban settlements, both in terms of single interventions and settlement organization
Collective meanings	Strong landscape identity and historical-cultural value of the built environment	Collective meaning identified with ruins of historical heritage Fallen cathedrals, severely damaged towers became earthquake icons	Practices of cultural institutions and artistic/cultural initiatives as a means of dealing with earthquake consequences
Local community	City and local initiatives protect public and green places as public goods and places of community identification	More than 300 victims, more than 65,000 left homeless Emergency phase managed by Civil Protection and National Government – local communities and authorities not engaged Informal network of help	Personal actions and community initiatives in dealing with earthquake consequences, while waiting for institutional assistance and inclusion
Professional initiatives	Professional associations and initiatives educate and raise awareness about the value of public goods and public urban places	Emergency response policies involve volunteers in post-earthquake actions	Intense debate between professional associations, central government, and the Special Commissioner for Reconstruction processes
Spatial planning	"Struttura Urbana Minima" approach to rethinking urban organization in light of seismic risk prevention CLE Civil Protection Plans	Civil Protection coordinates the immediate disaster response and organizes a preliminary inspection of buildings to establish damage	Sustainable and responsible relationships with urban spatial resources
Legal framework	Individual regulations related to Disaster Events Law to manage the emergency after disasters	Department of Civil Protection and network of first responders	General Reconstruction Law Thematic ordinances for the reconstruction and local economic development
Emphasis of each disaster phase regarding spatial planning and natural risk resilience	Meeting possibilities of spatial resources, social needs and desired improvements	Emergency management Emergency response policies involve volunteers	Renewed focus on potential links to seismic security, energy efficiency, urban organization and safety, and local development

Tab.2 Perspectives of natural risk resilience of Central Italy 2016 Earthquake

The state of emergency was declared after 24 August, extended after the strong earthquakes on 26 and 30 October, and extended again after the four shocks on 18 January and the exceptional snowfalls that affected Abruzzo, Lazio, Marche and Umbria. An initial list of 17 municipalities affected by the earthquake emerged from the decree to defer tax obligations due to the severity of the damage suffered, which was issued by the Ministry of Economic and Finance on 1 September 2016. Subsequently, on 9 September 2016, due to the complex situation of the territories, the President of the Republic issued a decree to nominate an Extraordinary Commissioner of the Government for Reconstruction in the Regions of Abruzzo, Lazio, Marche, and Umbria. The Commissioner's task was to: i) coordinate state administrations in conjunction with Regional Presidents and Mayors and the National Anti-Corruption Authority, to define plans, intervention programs, necessary resources, and administrative procedures to reconstruct public and private buildings and infrastructure in the areas affected by the earthquake; ii) ensure, jointly with the Head of the Civil Protection Department of the

Presidency of the Council of Ministers, the necessary connection between the respective areas of coordination; and iii) report to the President of the Council of Ministers on activities and initiatives to achieve the objectives. Thus, while Dicomac proceeded with the emergency management regarding the aspects of immediate support to the population and economic activities, the Extraordinary Commissioner began to define the means to implement the post-earthquake reconstruction phase.

On 17 October 2016, the Decree Law 189/2016 was published, which regulated interventions to repair, reconstruct, assist the population, and recover economic activities in the four regions affected by the earthquake. The Law was based on several essential elements:

- division of interventions into two distinct phases (emergency and reconstruction) and related competences and activities between the Department of Civil Protection (responsible for activities in the emergency phase) and Special Commissioner (responsible for reconstruction activities);
- a highly centralized reconstruction structure with the Extraordinary Commissioner;
- as the pivot of the system and coordinator between the different authorities (at the national, regional, and local levels);
- significant involvement of the Institutions and Authorities to guarantee protection the legality and supervision of expenditures;
- the presence of regional structures (USR – Uffici Speciali per la Ricostruzione) to support the Regions in the reconstruction process;
- spending autonomy through exceptional accounting;
- the right of the Extraordinary Commissioner to make exceptions to ordinary laws, without prejudice to compliance with the general principles of the legal system, to give immediate impetus for reconstruction;
- a legal framework and a department organized around several institutional competent levels to define the strategic elements of the reconstruction.

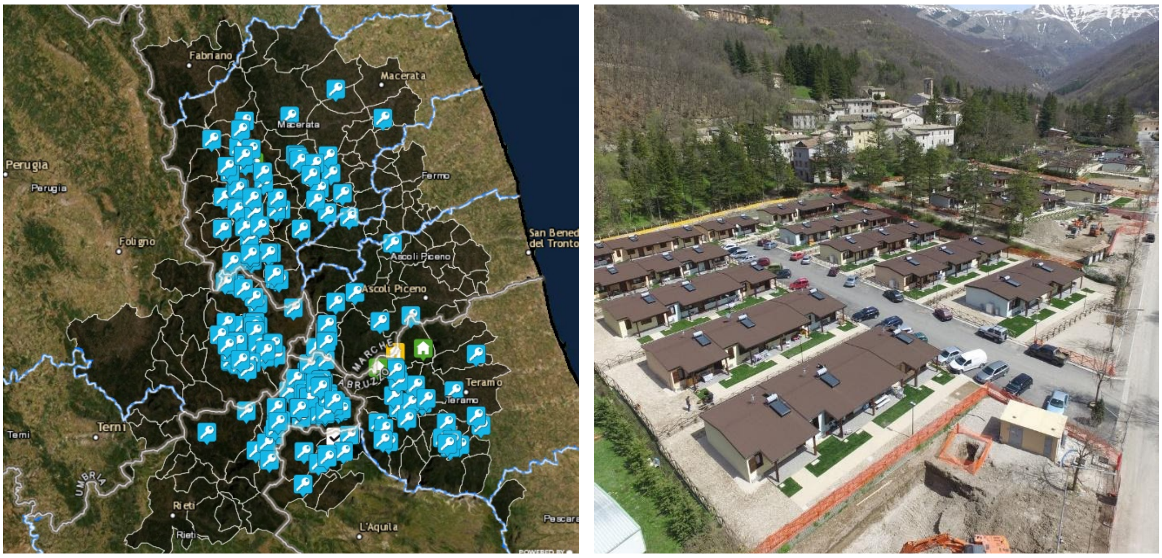
After the October earthquakes and expansion of the affected area, the Decree Law 189/2016 was converted with amendments in Law 229/2016 of 17 December 2016. The law introduced innovative elements to make the reconstruction approach more appropriate considering the increase in territories and municipalities affected by the seismic events of 26 and 30 October, for a total of 131 municipalities. The list was extended to 138 municipalities after the shocks in January 2017.

Reconstruction was divided into private and public reconstruction, and the Decree Law defined not only the reconstruction activities, but also the methods to disburse and report contributions. The implementation of the Decree Law provided a robust system for monitoring the reconstruction process, not only in terms of physical reconstruction, but also to support the economic regeneration of the territories.

The commissioner formally launched the standardization activity to implement the principles and objectives in the Reconstruction Law on 10 November 2016, with the publication of Ordinance nos. 1 and 2. To date, there have been four Extraordinary Commissioners, and 110 Ordinances have been published with specific indications for reconstruction.

The emergency phase

In Italy, regional contexts differ widely, and most refer to the Operating manual when preparing Municipal or Inter-Municipal Civil Protection Plans (Italian Presidency of the Council of Ministers, 2007). In January 2019, 87% of Italian municipalities were equipped with municipal civil protection plans, with peaks of 100% in some regions and only one region with a percentage below 50% (Sicily). Among the most critical points, emergency planning is not designed as a process of continuous updating; community engagement in the various phases of the emergency planning process is mostly expected but not practiced; methods of construction in event and risk scenarios do not reference any prefiguration of possible chains between primary and secondary events, which may constitute one of the main factors in the failure of the response; and municipal or inter-municipal Civil Protection Plans are not integrated into ordinary planning or specific sector planning. With this context, after the 24 August earthquake, the Civil Protection provided 43 reception areas and temporary solutions. The shocks in October represented a turning point in assistance for the population due to the high number of people left homeless and winter's imminent arrival. Most of the affected population was forced to leave their towns, with housing in hotels and accommodation facilities along the coast. Residential container solutions — integrated with modules for offices, services, common rooms, and cafeterias — were adopted for citizens unable to leave their territories.



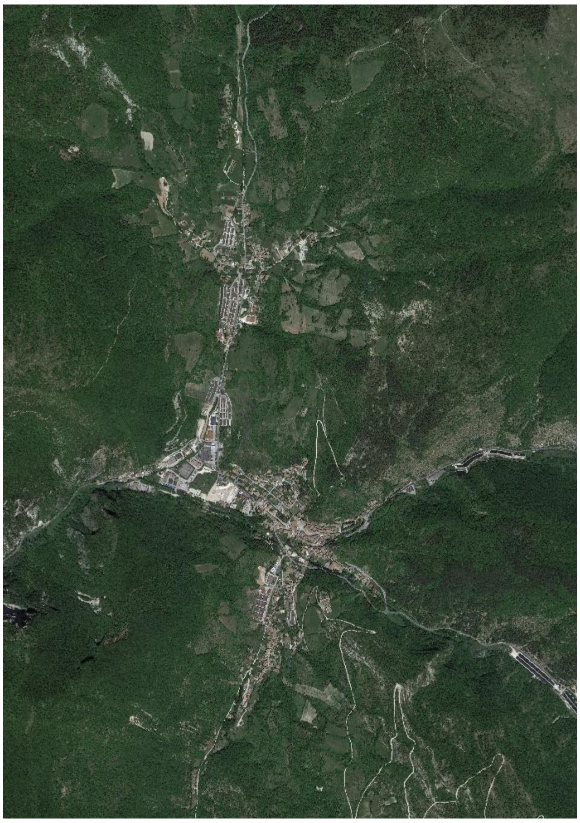
(a) (b)

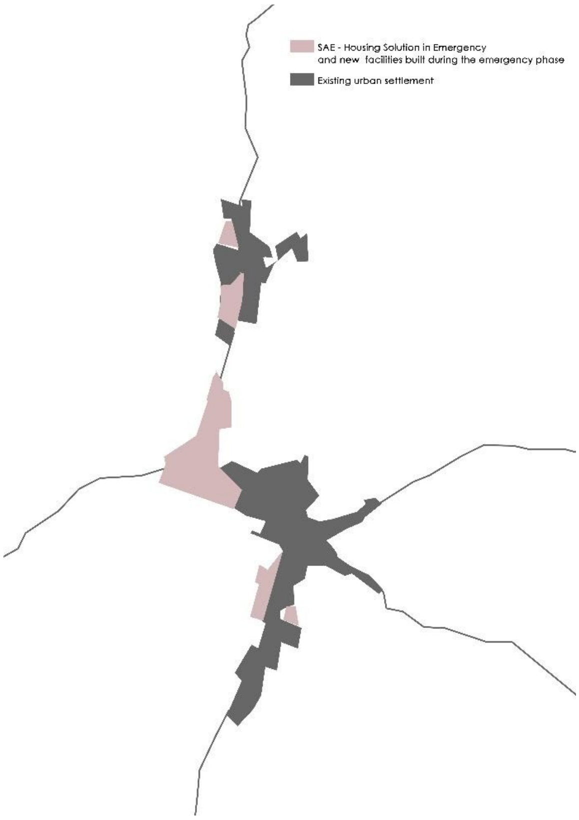
Fig.1 (a) Map of the distribution of the 228 SAE – Emergency Housing Solutions in the area affected by the earthquake; (b) Examples of SAE – Emergency Housing Solutions in Ussita – Location Pieve Capoluogo

In the meantime, the Department of Civil Protection activated specific contracts to build Emergency Housing Solutions (SAE) for citizens whose homes were uninhabitable or in the "red zone", so they could live in the affected areas until the end of the reconstruction (Fig.1a,1b). SAEs are removable and temporary convertible solutions of 40, 60 and 80 square metres, made with a wooden frame, and respect energy-saving and seismic risk prevention principles. SAEs are built fully furnished and connected by pedestrian paths and green areas, suitable for any climate conditions, and without architectural barriers to guarantee the accessibility of all users. The new settlements were built under exemption from the current planning system and rules in the name of the emergency and the need to house the resident population.

A total of 228 settlements were built to offer safe housing and allow the population to remain in the territory. In fact, besides the issue of dealing with the aftermath of that tragic disaster, the area in question featured (and still does) multiple disadvantages (Pierantoni & Sargolini, 2020; Shirvani Dastgerdi et al., 2019). These include the systemic, chronic crisis of inland areas, which represent a large part of the seismic area (namely, the demographic, social, and economic decline parallel to the growth and success of large urban systems along the coast and valleys) and the financial crisis of 2007, which has not truly been overcome. Construction was concluded in 2018.

While this construction has allowed people to be accommodated safely and comfortably for the entire duration of the reconstruction process, the location of the areas and the new urbanizations have changed the urban landscapes in most cases (Fig.2a, 2b). Entirely new settlements were built alongside existing historical ones, sometimes with significant impacts on the landscape. This raises further questions and challenges about the future of these areas when the historical building heritage is usable again (Stimilli & Sargolini, 2019).





(a) (b)

Fig.2 (a) Orthophoto of the changed (land/urban) scape after the emergency phase in the case of Visso; (b) Diagram of relationships between existing (land/urban) scape and new facilities of SAE – Emergency Housing Solutions (pink) in the case of Visso, built during the emergency phase

What emerges from the Italian experience is that emergency management must be planned in advance and cannot be achieved without implementing profound interaction with the urban and territorial planning system, while remaining a technical engineering activity. Many aspects of planning and programming can foster better resilience of the communities concerned, from improving living conditions and job opportunities to environmental sustainability and quality of health, from training individuals to strengthening economic and social organizations, public institutions, and territories. In this sense, emergency planning should be intended as prevention planning, focusing on the interaction with the populations concerned by adopting the citizen-science paradigm in the relevant phases of the emergency cycle.

The recovery phase

After the series of events, 49,954 private buildings were destroyed or made unusable, and 30,392 were damaged; around 1500 public buildings were damaged, and about 1000 churches were severely damaged.

As of June 2020, 13,948 requests for grants to reconstruct private buildings have been submitted. Of these, 5,325 were accepted, 678 rejected, and 7,945 are currently being processed.

The various ordinances issued by the Commissioners have identified and financed the restoration of 1,405 public buildings (including 250 schools), 942 churches, and also 172 micro-zoning plans for seismic prevention and 94 perimeter enclosures around the most affected centres. Eighty-six public buildings projects were implemented and completed, and another 85 are in progress; 100 churches have been restored, with another 45 construction sites open. The recovery phase particularly focuses on the attempt to coordinate individual interventions and integrate building reconstruction with energy efficiency and sustainability.

Ordinance 25 (23 May 2017) and Ordinance 39 (8 September 2017) are the two regulatory references for spatial planning. The first defines the criteria according to which the Regions see to the perimeter of the centres and settlements of particular cultural interest or parts thereof which were most affected by seismic events and in which individual interventions (reconstruction, repairs with overall seismic reinforcement and repairs with point-like reinforcement) must be coordinated and implemented through specific local urban plans. The second defines the guiding principles and general criteria to define and implement local urban plans for reconstruction interventions in historical centres and settlements of particular cultural interest. It also introduces the "Documento Direttore per la Ricostruzione (DDR)", which is a strategic non-binding document to address reconstruction by providing a strategic framework to guide actions and individual interventions on the local scale. Since it represents a voluntary, independent act for a single municipality, drafting a DDR allows for the public participation of local communities to define and outline the general reconstruction strategy and is highly recommended for municipalities with more extensive and severe seismic damage where emergency interventions have changed the urban landscape. The DDR is meant to reconsider the organization of the urban system as a whole to raise the level of safety (based on the Minimum Urban Structure approach) and improve the functionality of the services offered to local communities, relating the existing settlement to the new and restored settlements due to emergency interventions (Fig.3). Ordinance 39 introduced the DDR with the aim of integrating and coordinating the implementation of the urban local plans defined under Ordinance 25/2017, orienting public and/or private investments in line with the strategic framework, and updating existing urban planning tools and local plans. At present, only a limited number of municipalities have begun the participatory process to define the Strategic Document for Reconstruction. Some municipalities, such as Arquata del Tronto, have started and already concluded the process; others, such as Caldarola and Castelsantangelo sul Nera, are launching the participation process.

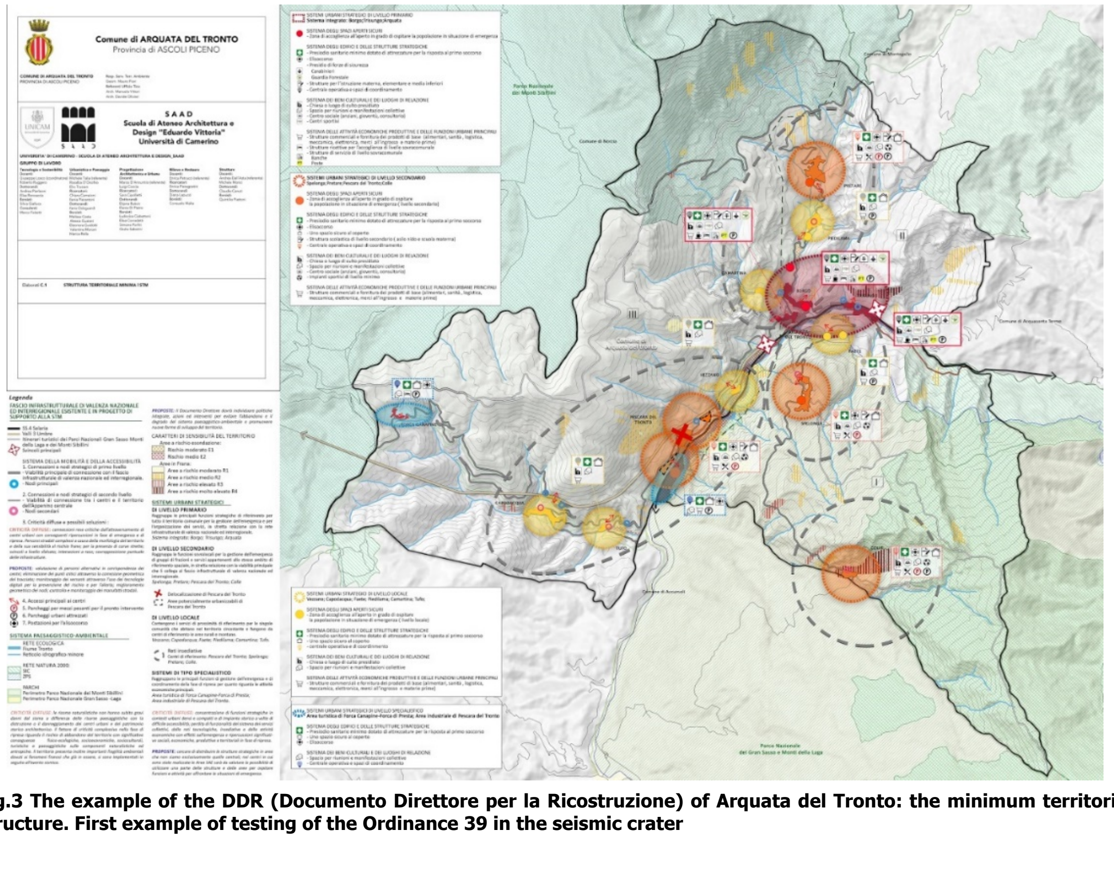


Fig.3 The example of the DDR (Documento Direttore per la Ricostruzione) of Arquata del Tronto: the minimum territorial structure. First example of testing of the Ordinance 39 in the seismic crater

3.4 Zagreb 2020 Earthquake

The Croatian capital of Zagreb was hit by an earthquake on 22 March 2020, with a magnitude of 5.6 on the Richter scale, in the midst of the COVID-19 quarantine. This was followed by a strong 5.0-magnitude aftershock. The restrictive measures implemented on a national level to slow the spread of COVID-19 made the immediate response and comprehensive earthquake recovery (Tab.3) even more demanding (Government of the Republic of Croatia, 2020). At the same time, the quarantine forced the majority of citizens to stay at home indoors, which contributed to low casualties. Although there was no major collapse of city blocks or complete breakdowns of individual buildings, the total damage was spread over a large, densely built and architecturally sensitive urban area (Ministry of Culture and Media, 2020).

Perspectives on natural risk resilience of the Zagreb 2020 Earthquake	**Pre-shock** Preceding earthquake Stillness phase	**Shock** Earthquake force and action Emergency phase	**Aftershock** Earthquake reactions and effects Recovery phase
Natural disaster	The Great Zagreb 1880 Earthquake M6.3	Zagreb 2020 earthquake and aftershock, M5.5 and M5.0, COVID quarantine	Series of lower magnitude earthquakes, COVID fluctuations
Area affected	Zagreb Urban Agglomeration 1,000,000 inhabitants 2.825 km^2 area	City of Zagreb, Zagreb County and Krapina-Zagorje County declared state of emergency	Act on Reconstruction of earthquake-damaged buildings in the City of Zagreb, Krapina-Zagorje County and Zagreb County
Protected cultural heritage	Immovable and movable cultural goods Cultural-historical units Protected and preventively protected	Most severe damage on Historical Urban Ensemble Damage to sacred/public buildings, museums, galleries and sacred inventories	Bad overall state of cultural heritage funds is evident Old questions about archives, implementing enhancement, defining conservation model
(Land/Urban)Scape heritage	Heterogenous heritage, urban picture and value of the whole of Upper and Lower Town can be applied to all of Zagreb	Zagreb urban picture is damaged by fallen chimneys, gable walls, damaged roofs, collapsed towers and domes, endangered by not restoring existing heritage	Focus on Historical Urban Ensemble of Zagreb, overlooking the wider historic and cultural context
Collective meanings	As the Croatian capital, Zagreb houses the majority of state functions, cultural institutions, and contents	Collective shock identified in material ruins of empty town Fallen cathedral towers and severely damaged buildings become earthquake icons	Urban identity shaken Practices of cultural intuitions and artistic interventions – dealing with earthquake consequences
Local community	City and local initiatives protect public and green places as public good and places for community identification	One dead, dozens wounded, thousands left homeless and hundreds of thousands living in damaged homes Informal assistance network	Personal actions and community initiatives in dealing with effects, while waiting for institutional assistance
Professional initiatives	Professional associations and initiatives educate and raise awareness about public good and the value of places	Emergency response policies involve volunteers in post-earthquake actions	Professional publications Amendment of professional association on Renewal Act Professional conferences
Spatial management	Croatian National Platform for Disaster Risk Reduction National Disaster Risk Management Strategy finalized in 2020	Civil Protection coordinates the immediate disaster response and organizes preliminary inspection of buildings to establish damage	Sustainable and responsible relationships with urban spatial resources
Spatial planning strategies	Spatial planning hierarchy in Croatia differentiates strategic from implementation plans of state, County, City/Municipality, and local level	Ministries coordinate short and long-term support, preparation of application for EU Solidarity Funds (EUSF)	Program for comprehensive renewal of the Historic Urban Ensemble of Zagreb Pilot Project of Block 19 to test renewal models
Legal framework	Regulatory framework in two fields covered by Building Act and Physical Planning Act	Current regulations used to guide and establish obligations for immediate reconstructions	Reconstruction Act primary goal – achieving mechanical resistance, secondary is overall urban renewal Fund for Reconstruction Expert Council for Reconstruction
Emphasis of each disaster phase regarding spatial planning and natural risk resilience	Meeting possibilities of spatial resources, social needs and desired improvements	Emergency management Emergency response policies involve volunteers	Post-disaster and urban renewal policies focused on the most severely damaged protected cultural/historical core

Tab.3 Perspectives of natural risk resilience of Zagreb 2020 Earthquake

Zagreb is found at the tectonic junction of the Alpine-Panonian and Dinaridic blocks (Ivančić et al., 2006). Mount Medvednica and the surroundings of Zagreb belong to a wider seismotectonic area in the border zone between the western and central part of the Pannonian Basin lying towards the Alpine and Dinarides blocks

(Kuk et al., 2000). Zagreb has a history of periodic earthquakes, with The Great Earthquake occurring in 1880. This brought devastating consequences to the city but is considered a major catalyst for the rapid development of Zagreb at the end of the 19th century. The Lower Town, a historical town of urban blocks, was formed at the turn of the 20th century. The Lower Town and medieval Upper Town are protected as the Historical Urban Ensemble of Zagreb, which suffered the most damage in the 2020 earthquake (MCM, 2020) and are therefore in need of renewal.

The area most affected by the 2020 earthquake[6] is the Zagreb Urban Region[7], which corresponds to a functional area structuring the territory, social phenomena, economic factors, heritage and (land/urban) scape values, and territorial coherence (CEMAT, 2017). The Zagreb Urban Region includes the City of Zagreb, Zagreb County, and Krapina-Zagorje County, with a quarter of the Croatian population. Even though the Reconstruction Act[8] covers all three administrative areas, the renewal policies are focused on the protected cultural-historical core[9], revealing the need for integral urban region renewal in the long-term process of post-disaster renewal.

The earthquake greatly damaged the protected cultural heritage, not just the Zagreb cultural-historical complex, but individual cultural properties located in the wider city area and neighbouring counties (MCM, 2020; Damjanović, 2020). The systematic analysis and inventory of damage through an inter- and transdisciplinary approach, and the individual conservation of each protected element of the heritage regarding recognized values, contextual integrity, and authenticity are needed to implement conservation renewal. The responsibility to protect monuments for disaster preparedness and prevention (Aničić, 2000) also protects both human lives and the heritage by presenting the city heritage as more than just a built structure.

The value, authenticity and integrity of the Zagreb urbanscape heritage derives from the heterogenous whole that goes beyond the cultural-historical core and integrates a range of urban characteristics, structures, and environments into a complex urban picture showing versatile layers of urban development. The greatest damage from the earthquake occurred to residential buildings[10] with fallen chimneys, collapsed gable walls and cornices, and damaged roofs, revealing neglect in the urban core and changing the urban picture. The threat of losing urban diversity, authenticity, and genius loci should be considered in urban and architectural renewal. The urban and natural landscape must be regarded as non-renewable heritage resources, promoting contemporary interventions that are integrated within a wider urban system, respecting the local context and upgrading existing values for the city. Initial personal and collective shock was identified with the material ruins of the earthquake-stricken city but also with the fear of an emptied urban centre and the local community's abandonment of Lower Town. The most severely damaged buildings and city symbols became the icons[11] of the Zagreb 2020 earthquake (Fig.4a, 4b) generating commemorative value. The shaken urban

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6 The preliminary assessment of damage to buildings, organised by the Civil Protection Headquarters, reported 26,334 inspected buildings, from which 19,746 are usable, 5,177 are temporarily usable and 1,411 are unusable.

7 The Zagreb Urban Area is one of six case study areas of the international scientific project SMART-U-GREEN – Governing conflicting perspectives on transformations in the urban rural continuum, funded from the EU Horizon 2020, grant agreement No 693443, duration from 2017 to 2021, coordinated by Matthijs Hisschemoller from DRIFT. The research involves cases of Drechtsteden, Regione Marche, Grand Reims, Zagreb, Pskov and Mahilioŭ.

8 The Act on Reconstruction of earthquake damaged buildings in the City of Zagreb, Krapina-Zagorje County and Zagreb County was passed on 11th September 2020.

9 The Reconstruction Act prescribed the preparation of the Program for the Complete Renewal of the Historical Entity of the City of Zagreb, and the Institute for Physical Planning of the City of Zagreb is in charge of it.

10 The housing sector is most affected by total losses (57%), followed by business (29%), health (10%), culture and cultural heritage (3%) and education (1%). Overall 78% of the damage and losses are in the private sector, and 22% in the public sector (Government of Croatia, 2020).

11 The Zagreb cathedral was particularly badly damaged. The cross-adorned top of the southern tower fell from the cathedral, while the north top was severely weakened and removed on April 17th. Another icon of the 2020 earthquake is the housing building in Đorđićeva street from which the gable wall toppled on the street.

identity has been reinforced by cultural practices, artistic interventions, and social recognition that present various means of dealing with the consequences of the earthquake[12].

The development of informal practices in Zagreb was on the rise[13] before the earthquake, mirroring decreasing trust in institutions and a formal framework regarding private interests to the detriment of the public good. In overcoming the consequences of the earthquake, personal actions and local community initiatives formed an informal network while waiting for institutional assistance and financing. A strong cultural identity, vivid society, and community inclusion is vital for the process of post-disaster renewal. The renewal of public space, as the space of life and a place for collective identification, can contribute to creating new values for the community. New renewal policies emerged by involving professionals and volunteers in post-earthquake emergency actions[14]. Professional initiatives continued to raise awareness about public goods and the value of public places[15], promoted publications on construction and urban renewal (Crnogorac et al., 2020; Jukić et al., 2020), discussed amendments to the Renewal Act, and organized professional conferences to educate the public and offer concrete measures to deal with the long-term consequences of the earthquake.

Spatial management regarding disaster risk reduction began in 2009 with the establishment of the Croatian National Platform for Disaster Risk Reduction and adoption of the national Disaster Risk Assessment in 2019. Despite earthquakes being recognized as a major danger, risk-reduction management is spread across multiple sectors (Government of the Republic of Croatia, 2020). Spatial management in post-disaster circumstances needs to address disaster risk reduction as well as sustainable and responsible relationships with urban spatial resources. The spatial planning hierarchy in Croatia defines the strategies and implementation plans for developing a safe, inclusive, resilient, and sustainable country (City Office for Strategic Planning and Development of the City, 2017). In the post-disaster situation, the City of Zagreb introduced the Program for Comprehensive Renewal of the Historical Urban Ensemble of Zagreb, prescribed by the Reconstruction Act, and the Pilot Project of Downtown Block 19 to test models. The proposed models for renewal that will be tested on Block 19 include aspects of conservation, construction, architecture, urban planning, energy, ecology, economics, law, and infrastructure.

(a) (b)

Fig.4 (a) Spatial consequences on 22 March 2020, the day of Zagreb 2020 Earthquake; (b)Spatial consequences on 22 April 2020, a month after Zagreb 2020 Earthquake

12 Cultural practices are hosted through live and online exhibitions dedicated to earthquake (institution units of the Croatian Academy of Arts and Crafts, Modern Gallery), virtual museums (Archaeological Museum), interventions and installations in devastated museum spaces (Art Pavilion in Zagreb), public exhibitions (European Square)...

13 Informal practices of city level are focused on social and environmental justice ('The City is Our','Right to the City','Green Action') and on a local level focused on safeguarding individual public places from private interests ('Keep Our Park – Savica', 'For What? For Kajzerica!', 'Parkticipation', 'The Blue Horseshoe').

14 Engineers, firemen and professional climbers assisted in removal of the structurally damaged chimney. Preliminary inspections of buildings were performed by civil engineers and architects – volunteers.

15 Professional initiatives 'Zagreb for Me', 'City Acupuncture', '1PercentForCity'.

One of most important steps in the recovery process is the adopted Reconstruction Act, which regulates reconstruction methods and procedures and the means of recovering or removing buildings damaged or destroyed by the 2020 earthquake (Ministry of Culture and Media, 2020). The primary goal of the Reconstruction Act is to achieve the mechanical resistance of damaged buildings to ensure the protection of lives and health. The secondary goal is the urban renewal of Zagreb. The funding expected to rebuild family houses and residential and commercial buildings is just a part of the comprehensive renewal that is needed.
The 2020 earthquake and the pandemic highlighted existing planning, spatial, social, economic, and cultural problems in Zagreb, the poor state of the overall cultural heritage and housing sector in historical urban areas, and the need for regional cohesion and community inclusion in spatial management decisions. The emphasis on sustainable development in the pre-shock phase, emergency management in the shock phase, and post-disaster/urban renewal of the most severely damaged protected cultural-historical core in the aftershock phase of the Zagreb 2020 earthquake reveal a tendency towards post-disaster mitigation rather than natural disaster resilience. Dealing with the consequences of the earthquake and the course of the pandemic should suggest that there are no means of restoring the former state and 'building back better', but that an opportunity is presented to 'build forward better'.

3.5 Comparative analysis of researched cases regarding goals of different approaches to disaster resilience enhancement

By learning from past lessons and tendencies towards future perspectives, this comparative analysis focuses on the challenges of post-disaster change in Central Italy and Zagreb. In the cases compared and researched, the perspectives of natural risk resilience are recognized as different approaches to natural disaster change and challenge (Tab.4). The comparison relates to setting goals for different approaches to enhance disaster resilience. The different approaches and related goals are organized not to presume the hierarchy, order, or importance of components of the resilience enhancement process, but the relationships that lead to increasing comprehensive natural risk resilience.
The comparison of the natural disaster processes in Central Italy and Zagreb reflects common changes and challenges, lessons and examples of best practices that can be learned from Italian experience, and stimuli that arise from tendencies in Zagreb's ongoing disaster recovery. The approach to earthquakes in both Italy and Croatia is aimed at monitoring seismic activity that feeds into the Earthquake Notification System[16] and implementing the Disaster Risk Management Strategy[17]. The objective of post-earthquake renewal focuses on achieving the minimal urban structure in Italy and earthquake-resistant construction in Croatia.
The (land/urban) scape heritage approach appeals to preserving landscape and urbanscape values by affirming the identity of the (land/urban) scape and supporting cultural continuity. For Italy, the tendencies of post-earthquake emergency solutions to shape divergence towards the historical landscape and its inherited values were not acknowledged on time, thus leading to the need for (land/urban) scape renewal. The lesson should not be repeated in Zagreb, which challenges urban and architectural renewal by affirming urban identities. Cultural heritage must be protected as the expression of past legacy, an asset of sustainable development, and a reflection of what is left to future generations. The challenge of Central Italy in contrasting perspectives on conservation requirements and the need for innovation and seismic renewal has not been fully experienced

[16] The Earthquake Notification System (ENS) is one of the most important systems in earthquake consequences mitigation, enabling prompt reaction and assisting civil protection in rescue operations. Italy already has developed ENS (USGS, USAID), while the Republic of Croatia is still in the early stages of developing ENS (Republic of Croatia, 2019).

[17] The Croatian National Disaster Risk Management Strategy is in preparation and should be completed by the end of 2020 (Government of Republic of Croatia, 2020).

in post-earthquake Zagreb, which aims to successfully apply an inter- and transdisciplinary approach to conservation.

Approaches to disaster change and challenge	**Central Italy 2016 earthquake**	**Zagreb 2020 earthquake**	**Goals of different approaches to disaster-resilience enhancement**
Seismic approach	Seismic renewal "Minimum urban structure"	Seismic renewal Fire hazard renewal Construction renewal	Monitoring seismic activity Seismic resistance
(Land/Urban)scape heritage approach	Mitigate divergent post-earthquake emergency solutions and traditional structures (Land/urban)scape renewal	Urban renewal Architectural renewal Urban identities affirmation	Preserving (land/urban)scape values Affirmation of (land/urban)scape identity Cultural continuity Progress tendencies
Cultural heritage approach	Contrasting perspectives of conservation renewal and innovation and post-earthquake renewal	Conservation renewal Need for inter- and transdisciplinary approach	Legacy protection Development asset Reflection of inheritance
Symbolic approach	Cultural and musical events Walks and itineraries across the seismic crater Artistic expositions Landscape identities affirmation	Artistic interventions Cultural practices Urban identities affirmation	Give meaning Intellectual awareness Knowledge transfer Cultural education Affirmation of identity
Local community approach	Exclusion of local community in emergency management decisions Reconstruction Law requires involvement of communities in the decision-making process	'Pro-forma' participation Awareness of collective and personal identity Citizen actions Informal network of help	Developing personal and collective responsibility Raising awareness Prosperous and resilient communities Public participation and community inclusion
Professional approach	Economic incentives for cooperation between individual interventions Need for inter- and transdisciplinary approach	Need for inter- and transdisciplinary approach to urban renewal	Provide instruction Direct progress tendency Public education Raising awareness
Spatial management approach	Emergency management with new living solutions (SAE) Landscape and urban renewal and reconstruction Energy efficiency	Urban and structural renewal Communication renewal Ecological renewal Infrastructure renewal	Fostering spatial resources Public good and interest Authentic, context-integrated interventions Concrete procedures
Regional approach	Functional urban and rural renewal	Functional urban renewal Integration of historic values, current resources, and needs	Fostering regional resources Living space, social recognition Territorial heritage
Spatial planning approach	Strategic Reconstruction Document Local executive plans for reconstruction	Comprehensive renewal Pilot project for testing models Comprehensive digital interoperable platform	Concrete strategies Safe, inclusive, resilient, and sustainable spaces Comprehensive renewal
Legislation approach	General Reconstruction Law Thematic ordinances for reconstruction and local economic development	Reconstruction Act Legal renewal Economic renewal	Concrete protocols Legal regulation

Tab.4 Approaches to of natural disaster change and challenge of the Central Italy 2016 and Zagreb 2020 Earthquake

Symbols and representations signify intellectual awareness, knowledge transfer, and cultural education in the course of restoring identities and giving meaning to resilience enhancement. The affirmation of identity is present in both case studies through cultural and musical events, walks and itineraries to promote the landscape heritage of Central Italy, and artistic interventions and cultural practices to endorse the urban identity of Zagreb. The problem of 'pro-forma' public participation and exclusion of the local community is evident in Central Italy in post-earthquake emergency management and in Croatia in spatial management and planning. Therefore, local communities must be encouraged to prosper into a robust community, contributing to developing personal and collective responsibility, raising awareness about spatial, cultural, and symbolic values, and empowering them through public participation and community inclusion.

The use of professional knowledge in both Italy and Croatia demands cooperation between different interventions, inter- and transdisciplinary approaches that advance public education and awareness by providing instruction and directing progress tendencies in disaster-resilience enhancement. Spatial management sustains spatial resources, public goods, and interest through concrete procedures that claim authenticity and integration (ICOMOS, 2013). Both cases — Central Italy and Zagreb — indicate the need for authentic, context-integrated interventions that will not create new needs for urban, structural, and energy renewal. A regional approach is needed in both post-earthquake cases to foster resources of living space, social cohesion, and territorial heritage by interrelating historical urban cores, urban, suburban, and rural structures with the natural landscape.

Spatial planning strategies promote inclusive, safe, resilient, and sustainable spaces that benefit from historical values, current resources, and actual needs. In Italy, concrete spatial planning strategies to achieve comprehensive renewal regard the Strategic Reconstruction Document and local executive plans for reconstruction, while in Croatia they regard the Reconstruction Act for earthquake-stricken counties, the local programme for comprehensive renewal of the protected cultural/historical core, and the pilot project of one Lower Town block to test versatile renewal models. Legal framework in both countries – Italy and Croatia support the spatial management procedures, spatial planning strategies, and concrete protocols through acts and regulations that uphold legislation regarding disaster resilience enhancement. The thematic ordinances developed for reconstruction and the local economic development of Central Italy serve as lessons for legal regulation in Croatia.

A comparison of the changes and challenges in Central Italy and Zagreb shows differences that reflect local problems in dealing with earthquake consequences, common threats that must be overcome, but also shared goals. In formal policies regarding the legal framework, spatial planning, territorial cohesion, spatial management, professional engagement, and seismic monitoring activities, post-earthquake renewal is identified as a common goal. Informal practices in the community regarding collective symbols, cultural and (land/urban)scape heritage, expand the intent to identity affirmation. The problems of post-earthquake Central Italy and Zagreb lie in differing formal renewal policies, plans, and strategies to affirm the spatial, communal, and cultural identity. They arise from informal practices and actions taken by the community when trust in institutions declines and they focus on post-disaster mitigation that challenges natural disaster resilience. Shared difficulties that arise from post-earthquake renewal and the affirmation of identity in Central Italy and Zagreb indicate that not all aspects of disaster resilience are considered. For example, the renewal and integration of the historical urban core, urbanized area, and functional region as a whole should be improved, the inclusion of community and citizen groups should be encouraged, and intangible values such as the landscape picture, image of the city, genius loci, and authenticity that arise from affirmation of (land/urban) scape and unprotected cultural heritage should be sustained.

When correlated with developing-high quality (land/scape) scape, raising social integration standards, enhancing culture, and affirming identity, emergency management and (land/urban) scape renewal in the course of natural disasters can address long-term goals of spatial management, spatial planning strategies and legal regulations that deal with consequences with a view to reducing future risks and enhancing the current resilience. The various ties, links, and connections between different approaches to post-disaster change and challenges interrelate all dimensions of disaster resilience, thus fostering holistic natural risk resilience.

4. Conclusion

4.1 Contributing to holistic natural risk resilience by interrelating (land/urban) scape resilience models

The contribution of this research is twofold: to interrelate (land/urban) scape resilience dimensions and produce models to foster holistic natural risk resilience. The research on fostering natural risk resilience is situated in the wider body of knowledge by reintroducing (land/urban) scape dimensions. As primary (land/urban) scape dimensions, space, society, and culture are tied to perspectives of natural risk resilience, and to consequences and threats of natural disasters that arise from the comparison of the Central Italy 2016 and Zagreb 2020 earthquakes. By grouping perspectives of natural risk resilience and connecting to extended (land/urban) scape dimensions, the dimensions of (land/urban)scape resilience are introduced. Besides the spatial, social, and cultural dimensions, nature, planning, and time are also included (Tab.5). The temporal dimension of (land/urban) scape resilience arises from the perspective of natural risk resilience as a process.

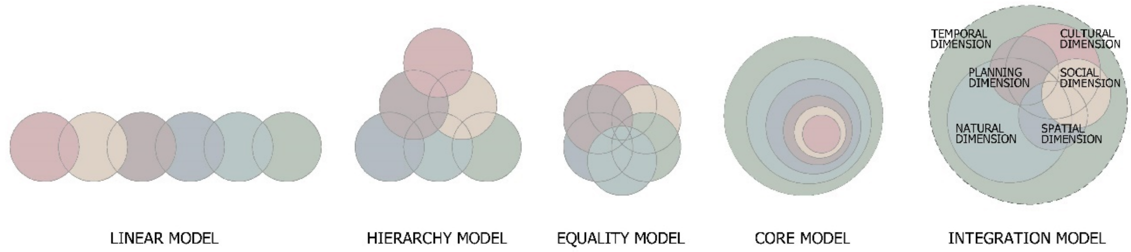

Fig.5 Interrelation structures of (land/urban) scape resilience dimensions as integration models

Different connections between the (land/urban) scape resilience dimensions are presented as diagrams of interrelation structures (Fig.5), which show that order, hierarchy, or importance do not promote holistic natural risk resilience. Interrelation structures are used to present complex relationships between the components of comprehensive notions such as landscape (Swanwick, 2002), sustainability (United Nations, 2015), resilience (ICOR, 2021; Dinshaw & McGinn, 2019; Kwok et al., 2016), and different forms of disciplinarity (McPhee et al., 2018). Linear models present sequential connections of components that form singular or multiple (Shirvani Dastgerdi et al., 2020a; Chambers et al., 2019) branches of implications. Interrelation structures reveal various models of interconnecting the resilience dimensions: hierarchical models (Shirvani Dastgerdi et al., 2020b) and combinations to linear models (European Commission, 2018), equality models recognized as multilayered models (Dinshaw & McGinn, 2019), and combinations of core and equality models (ICOR, 2021, McPhee et al., 2018, United Nations, 2015, Swanwick, 2002). Fostering holistic natural risk resilience is achieved by comprehensively interrelating the resilience dimensions in the integration model (Fig.5). It is presented as an open platform that can also support other resilience dimensions and other means of interrelation. Achieving holistic natural risk resilience is possible when comprehensive perspectives are integrated and interrelated such that they benefit from each other.

The diversity of resilience dimensions analysed in the cases of earthquake-affected areas in Central Italy and the Croatian capital of Zagreb induces various models of natural risk resilience (Tab.5). Different resilience models are introduced as a means of dealing with consequences and threats regarded by different perspectives of natural risk resilience. Specific models such as ecological resilience (Chambers et al., 2019; Wu & Wu, 2013; Folke, 2006), socio-ecological resilience (Folke, 2006), engineering resilience (Folke, 2006), spatial resilience (Chambers et al., 2019), climate resilience (Dinshaw & McGinn, 2019), and social resilience (Kwok et al., 2016) are distinguished from comprehensive models as general resilience (Chambers et al., 2019) or organizational resilience (ICOR, 2021).

<table>
<tr><th>(Land/ Urban) Scape resilience dimensions</th><th>Perspectives of natural risk resilience</th><th>Consequences and threats of natural disasters</th><th colspan="3">Fostering holistic natural risk resilience</th></tr>
<tr><td>Natural dimension</td><td>Natural disaster</td><td>Damage to buildings and sectors of health, education, culture, heritage, business, housing
Neglecting interrelations between urban core(s), urban and suburban structures and the natural setting</td><td rowspan="5">Identity resilience model</td><td rowspan="2">(Land/urban) scape resilience model</td><td rowspan="4">Cultural resilience model</td></tr>
<tr><td rowspan="2">Cultural dimension</td><td>(Land/urban) scape heritage</td><td>Loss of genius loci and (land/urban)scape authenticity
Loss of cultural and (land/urban)scape diversity
Change in picture and image of the scape
Abandonment of liveable heritage cities/towns</td></tr>
<tr><td>Protected cultural heritage</td><td>Destruction of historic urban cores, settlements, ensemble, and heritage assets
General approach to all cultural heritage
Long-term process of heritage renewal
Contrasting perspectives between conservation requirements and innovation and seismic renewal</td><td rowspan="4">Social resilience model</td></tr>
<tr><td rowspan="2">Social dimension</td><td>Collective meanings</td><td>Losing sense of community – collective memory, symbols, and identity
Losing sense of belonging
Changes in cultural practices and traditions</td></tr>
<tr><td>Local community</td><td>Uprooting of communities, home abandonment and emptied towns and settlements
Breakdown of social ties
Job losses and difficult transfer of business
'Pro forma' participation – community excluded from the process of post-disaster renewal</td><td rowspan="7">Economic resilience model</td></tr>
<tr><td rowspan="3">Spatial dimension</td><td>Professional initiatives</td><td>Ignoring professional instructions
Neglecting general public education
Lack of cooperation between/among professions, investors</td><td rowspan="6">Spatial resilience model</td></tr>
<tr><td>Spatial management</td><td>Emergency management for living solutions endangers long-term objectives
Favouring private interests to the detriment of the public
Interventions without context integration, authenticity and interrelations forming network
Gentrification, touristification, apartmenization, festivization</td><td rowspan="5">Planning resilience model</td></tr>
<tr><td>Regional approach</td><td>Focusing on worst affected/protected areas
Neglecting natural disaster resistance of the whole region</td></tr>
<tr><td rowspan="2">Planning dimension</td><td>Spatial planning strategies</td><td>Enhancement of spatial planning problems preceding the earthquake
Emergency requests pressure on spatial planning
Consumption of land and spatial resources with emergency solutions</td></tr>
<tr><td>Legal framework</td><td>Pressure on legal framework for emergency acts
Continual amendments of renewal acts
Community turning to informal practices and actions when trust and institutional tools fail</td></tr>
<tr><td>Temporal dimension</td><td>Process of resilience enhancement</td><td>Approaching comprehensive (land/urban) scape renewal and identity affirmation as a single action
Focusing on short-term benefits and disregarding long-term goals</td></tr>
</table>

Tab.5 Models of fostering holistic natural risk resilience

Different resilience models establish the means through which cultural heritage and communities contribute to spatial planning in the course of disaster risk reduction. Therefore, spatial planning needs to promote holistic natural risk resilience by strengthening and encouraging the integration of (land/urban)scape, cultural, identity, social, spatial, planning, economic, and other models that address multiple scales and temporal aspects of resilience (Chelleri et al., 2015).

Different interrelation structures that combine various models of natural risk resilience enhance spatial planning to develop beyond vulnerability assessment (ICOR, 2021; Dinshaw & McGinn, 2019; Borg et al., 2014), adaptability to disaster effects (ICOR, 2021; Chambers et al., 2019) and disaster recovery, restoration to the prior state and 'building back better' – towards the threshold concept to transform and 'build forward better' (Chelleri et al., 2015). Threshold concepts describe the core concepts that have to be mastered to think effectively from within a new paradigm (Loring, 2020). The roots of holistic resilience paradigm lie in international policies: the European Landscape Convention (Council of Europe, 2000; Council of Europe, 2016), European Green Deal (European Commission, 2019), Agenda for Sustainable Development (United Nations, 2015), and conventions recognizing the values of tangible and intangible cultural heritage for society (Council of Europe, 2005; UNESCO, 1972, 2003, 2019; European Commission, 2018) that exchange different perspectives towards the Hyogo Framework for Action 2005-2015 (UNISDR, 2005) and Sendai Framework for Disaster Risk Reduction 2015 – 2030 (UNISDR, 2015).

4.2 Implications of holistic natural risk resilience for spatial planning enhancement

Natural disasters destroy (land/urban) scape values, the protected cultural heritage, collective symbols and traditions, socio-cultural practices and networks, and have a direct impact on spatial resources that appeal to spatial planning with a view to enhancing the current resilience and reducing future risks. The Heritage Urbanism approach was applied to a historical overview of earthquake examples in the Apennine-Adriatic-Dinaride region and the most representative seismic events of the 21st century in Italy and Croatia were researched. The approach provided identifying factors and evaluation criteria and helped to read existing resilience models and form a new integrated model of holistic natural risk resilience. The implications of holistic natural risk resilience for spatial planning enhancement arise as the ultimate research conclusions.

Identifying factors in the natural disaster process derive from an exchange of (land/urban) scape dimensions and research aim. Perspectives on natural risk resilience that the spatial planning process should regard are based on extended identity factors of the natural disaster: 1. natural risk (natural disaster and area of influence); 2. cultural heritage (protected cultural heritage and (land/urban) scape heritage); 3. communities (collective meanings and local community); 4. spatial resources (professional initiatives and spatial management); and 5. spatial planning factors (existing spatial planning strategies and legal framework).

The evaluation criteria applied to a historical overview of the impacts of seismic activity on the Apennines-Po and Dinarides-Panonian regions, and the comparison of the Central Italy and Zagreb research cases include: 1. the three phases of the natural disaster process and 2. comprehensive challenges of natural disaster events regarding spatial planning. The established evaluation criteria show spatial planning to be a system that must function and guide progress through a stillness phase (pre-shock), emergency phase (shock), and recovery phase (aftershock) in the natural disaster process, and not as an ad-hoc reaction, adaptation to, or reduction of the destructive effects. Resilient spatial planning must address multiple spatial scales, multiple temporal aspects of resilience, various perspectives of natural disasters, and be integrated in all levels of spatial planning.

A comparison of the goals of different approaches to disaster resilience enhancement in Central Italy and Zagreb reflect local problems in dealing with the consequences of earthquakes, common threats that must be overcome, shared goals, and existing resilience models. Spatial planning can be enhanced by interrelating (land/urban) scape resilience dimensions and existing resilience models, thereby forming a new integrated holistic model. The holistic model therefore advances the values already present and develops an endogenous spatial planning approach. In the midst of constant risks from natural disasters, spatial planning should promote holistic natural risk resilience by strengthening and encouraging the integration of resilience models regarding the (land/urban) scape, culture, identity, society, space, planning, economics, etc. Fostering holistic natural risk resilience is therefore needed as a standard in spatial planning, (land/urban) scape and urban renewal, cultural affirmation and social identity, developing hearty communities, all professional outputs, and hosted by everyone who participates in designing and planning cities, settlements, and landscapes.

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Image sources

Fig.1a: Italian Civil Protection Department (http://www.protezionecivile.gov.it/en/risk-activities/seismic-risk/emergencies/central-italy-2016);

Fig.1b: Marche Region Special Office for Reconstruction (https://www.regione.marche.it/Regione-Utile/Terremoto-Marche/SAE-soluzioni-abitative-in-emergenza#Mappa-aree-SAE);

Fig.2a: Google satellite;

Fig.2b: Ilenia Pierantoni, Massimo Sargolini;

Fig.3: Documento Direttore del Comune di Arquata del Tronto (commissioned by the Municipality of Arquata del Tronto to the School of Architecture and Design of the University of Camerino. Scientific coordinator: Prof. Giuseppe Losco. Scientific Responsible for landscape and territorial planning: Michele Talia);

Fig.4a: author Leon Ladišić;

Fig.4b: author Ana Sopina;

Fig.5: author Ana Sopina;

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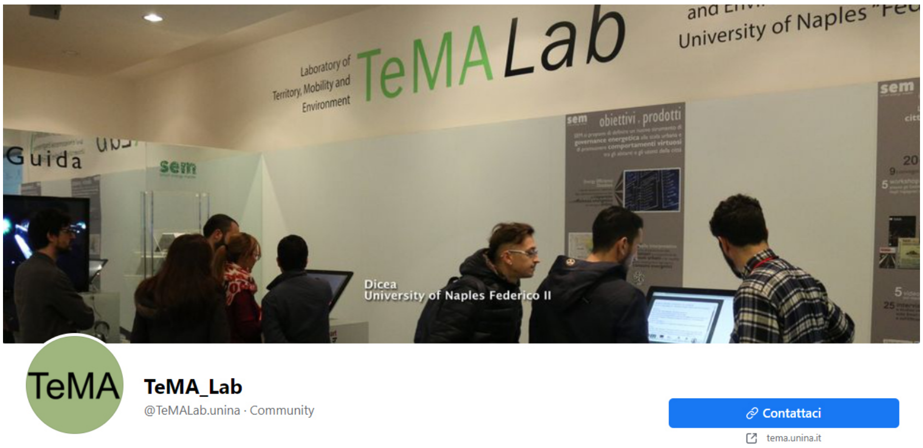

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The time profile of transformations in territorial governance

Towards a meeting point between urban planning and risk management

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Abstract

As a result of the close relationship with the School of Architecture founded in 1919, Italian urban planning has often been marked by a search for a difficult balance between spatial and temporal projections in plans, often favouring the former over the latter. Due to this unequal development in planning contents, territorial governance has shown a worrying loss of authority, which tends to generate evident contradictions when territorial planning is called to contend with problems deriving from the management of areas where urban planning forecasts must coexist with extraordinary provisions adopted following an earthquake or other natural disaster. In this recurring difficulty of finding space within ordinary planning procedures for measures designed to address the emergency, three starting conditions prove to be decisive. The first is the need to guarantee the availability of a rigorous cognitive framework to allow an increasingly complex and unstable planning system to be based on rich, detailed information. The second is the requirement to reduce the gap between the technical times necessary to develop planning tools and the necessary promptness for procedures to coordinate emergency policies. The third is the need to entrust strategic documents with the task of balancing the relationship between the short and long terms, both in urban planning and in emergency plans.

Keywords

Strategic planning; Decision-making system; Simplifying procedures.

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1. Introduction

The history of modern urban planning has often been marked by the search for a satisfactory balance between spatial and temporal projections in planning. This attempt has only rarely yielded the expected results. In the different phases crossed by our discipline, it indeed seems that the prevalence of the former over the latter has not only produced important changes in the shape of the plan, but has wound up decreeing the success or failure of public policies that were launched to overcome the main challenges that society has had to address over time.

Especially in Italy, the prevalence of a vision focused on architecture and urbanism in the *planning* culture has ensured that the solution to layout problems in many cases favours regulating land use and addressing the morphology and type of settlements, with the result that the study and definition of dynamics that would have characterized the change are overlooked. Due to this unequal development in the contents of planning, territorial governance rarely seems able to dialogue effectively with the public administration, and the conflict that results between a rigid, non-updated regulatory framework and the requests expressed from the local government to consider changes in the context lies at the heart of a worrying loss of authority of the urban plan. This tool both risks conditioning (and slowing) the proper unfolding of decision-making processes and does not always guarantee the correct *territorialization* of public investments.

Faced with the short circuit that tends to be generated between the ex ante forecasting of settlement transformations and the control that occurs as they materialize, further critical aspects are destined to arise when territorial planning is called to face problems deriving from the management of those areas where risk assessment is of fundamental importance. In such situations, the atemporal character of many urban planning predictions and the difficulty of quickly introducing the sometimes radical modifications dictated by the emergency has in many cases induced a drastic separation between the decision-making processes prescribed by urban planning legislation and the extraordinary provisions necessitated by a traumatic event such as an earthquake or other natural disaster.

As the earthquakes in Central Italy in 2016 and 2017 recently highlighted, the reconstruction process often seems destined to produce a conflict between general municipal planning tools and the reconstruction plan that is difficult to resolve. At the base of this divergence lies the difficulty of combining the objective of favouring the return of residents evacuated from the areas most seriously hit — with the attempt to support the rebirth of the social and economic framework of the context of reference — and the succession of numerous, often contradictory regulatory interventions (decrees and ordinances), requested in turn by politics, technicians, experts, or local administrations over the years. As has been widely shown, this has highlighted uncertainties, reconsiderations, and changes in governance, which certainly have not helped reconstruction or created the conditions for a new phase in developing the inland areas of the Central Apennines starting with an overall urban-planning and territorial vision. Precisely by virtue of the tendency to introduce criteria that are difficult to reconcile, first Ordinances 25/2017 and 39/2017 and then Ordinance 107/2020 seem to reference diverging interests and values.

Amid this clear difficulty of finding space in ordinary planning procedures for measures aimed to address the emergency, respect for three starting conditions may be decisive in the near future. The first is the capacity to guarantee the offer of a rigorous, exhaustive cognitive framework that, in addition to providing an organic representation of the state of the territory and its characteristic evolutionary processes, also provides the necessary data about exposure and vulnerability to develop *damage scenarios* for scrupulous consideration of the territorial risk. The centrality that knowledge would tend to acquire thus may be traced to the need for a planning system increasingly based on a rich, organized base of information; however, it is also necessary to consider that reference to a single analytical *corpus* can ensure that the most important decisions are taken in a public space where democratic interaction and trust in the principle of responsibility are exercised (Governa, 2014).

The second condition that should be protected regards then the need to favor the significant rationalization and acceleration of decision-making processes to reduce the *gap* that tends to grow continuously between the technical times needed to draft planning tools and the necessary promptness to coordinate emergency policies. Anticipating a consideration discussed later, the attempt to attenuate criticalities deriving from territorial governance subject to the deficiencies of a decision-making processes with double speed should ensure that the urban plan is not increasingly deemed useless in a period dominated as it is by uncertainty and risk (Talia, 2017b). This type of goals assumes much more efficient territorial governance, which in turn seems to allude to the recovery of *administrative discretion* that the recent "simplification decree" (Legislative Decree no. 76 of 16 July 2020) intends to promote.

Lastly, a third condition seems even more promising, in which strategic documents are viewed as a tool aimed at balancing the relationship between temporariness and permanence (Barca & Ricci, 2018), both in urban planning and in emergency plans. In fact, by adopting an approach of this type, it seems possible to validate the conviction that effective responses can be made to the request to closely assess decisions of collective interest and for frequent tests to ascertain their inclination to intercept the changes underway. Not only that. By assuming this new orientation, risk management can finally do away with binding tools, giving planning the task of defining the methodological *frame* in which to classify the limits of danger that public action should consider, and within which it will be possible to observe different intervention alternatives (Talia, 2020, p. 139).

2. Cognitive processes and the new tasks of urban planning

In the long and laborious transition that has affected territorial governance for some time now, the role of knowledge seems destined to assume increasingly significant importance. Expecting a more radical change in planning tools, the direction, speed, and results truly achieved by urban planning projects will depend rather heavily on the cognitive resources employed. In addition to assigning territorial research with unprecedented authority, at least in Italy, this new approach is clearly destined have a rather large influence on processes that contribute to decision-making. With regard to the relationship between general municipal planning and the reconstruction plan at the focus of this reflection, the availability of in-depth, updated cognitive frameworks can certainly facilitate dialogue and collaboration between these two different approaches to territorial governance. This search for appropriate forms of contact between these two types of plan evidently involves close attention to knowledge about questions related to securing the territory, a verification of the geological feasibility of reconstruction interventions, and the possible activation of positive trade-offs between two or more ecosystem services.

While discussion about the relationships between tactics and strategies had already marked the need to mobilize a large range of analytical knowledge and technical skills (Talia, 2017a), the shift to this new 'chapter' in reflection on the evolution of the plan prefigures a clear dilation of the area of interest, and it especially involves the need to investigate the implications of some concepts of fundamental importance for understanding the notion of risk. At the same time, this is followed by the need to clarify the type of future and margins of uncertainty that the plan should help to outline, which, in the case of reconstruction, should entail better anchoring to the time profile of the expected settlement transformations.

With regard to the first question, it is probably worth starting from the contrast between what many consider to be 'the risk as an objective reality that exists in the physical environment independent of whom and how it is perceived and represented … and those that instead assume risk as a *sociocultural construct*, in other words, as an experiential situation mediated by culture, knowledge, and values' (Cerase, 2017, p. 29, English translation by the author). The antithesis between these two readings of the notion of risk has obvious implications that are not only conceptual. Especially in the latter interpretation, the use of a *constructionist* approach to the issue of security shows that territorial governance can successfully control and manage risk factors by using, for example, a matrix to organize intervention alternatives and the thresholds of vulnerability that public action can, and in some cases *must*, consider.

But there is another issue that should be addressed, which regards the creation of scenarios for visions of the future and the awareness of risks that the plan should consider when evaluating its design contents. In this regard, it is necessary to start by considering the radical transformations brought about by technological innovation in the space-time relationships that preside over the reorganization of society and the new settlement structures that will arise from it. Since these changes seem destined to prevent the market economy from compensating once again — as was always the case in the past — with the tendency of the profit rate to fall by creating ever new spatial relationships, our view of the future prospects of our communities and urban systems must necessarily change and be equipped with new cognitive tools. Having to dispense with that radical change of the array of production, exchange, and consumption which had characterized the salient phases of the industrialization process (Harvey, 2011), the new geography drawn by electronic and telematic flows dictates an authentic jump in quality. If capitalism can therefore no longer adapt to technological progress, then post-capitalism is required (Mason, 2016, p. 14) and reflection on the future prospects of our communities and urban systems — including the Apennine regions and the others inland areas of Italy — will have to be equipped with new interpretational paradigms.

Faced with the new questions presented to territorial governance, cognitive processes will have to open more towards applied research, intertwining ever closer links with the ethical and political aspects of technical-administrative action. For decision-makers, *planners*, public administration employees, and the local communities themselves, it is a matter of making a sweeping turn, confirming a hypothesis already proposed by Albert O.

Hirschman, according to which the pursuit of knowledge, on a par with the search of beauty, well-being and safety, ‘contains within it its own reward’. Therefore, while the commitment made by citizens for the benefit of public happiness appears to have largely paid off (Hirschman, 1983, p. 111–7), the result is more interesting opportunities to enhance collective behaviour in contemporary society, on which new forms of collaboration and reciprocity can be based to remodel the frame of economic and social relationships.

In the perspective delineated by current and future strategies to overcome the pandemic crisis, a combination of consistent public and private investments can be hypothesized to favour scientific research, entailing significant modernization and securing the urban areas, and resolute advancement in technological standards. This involves the dual scope of significantly reducing emissions and increasing market opportunities for companies that offer functional products for such modernization, but also in this case the balance to be achieved when recomposing the main objectives of the urban and territorial agenda will have to rely on the renewed potential of the cognitive framework.

By virtue of the contribution offered by new information technologies, we can expect important progress in the acquisition, treatment, communication, and sharing of territorial and environmental data necessary to support multi-actor decision-making processes (big data management, development of sensors, urban intelligence, etc.). All this can evidently trigger a new alliance between urban planning and emergency management which, with the availability of an integrated system of knowledge, may be capable of following a more advanced synthesis of the respective priorities (Aven & Zio, 2018).

3. Towards the reform of administrative and control procedures in territorial governance

If we believe that the dialogue between urban-planning regulations and risk management should intensify in the coming years, it is necessary to ensure that the complexity and length of the procedures required by both disciplines are brought under control. Otherwise, we can expect the adoption of impromptu and ill-considered initiatives from both national and regional institutions, which having stopped expecting an

organic proposal for reform by Parliament or regional councils, could aim to drastically simplify decision-making and implementation processes. The consequence — we must be fully aware — would be the endangerment of fundamental tools of environmental protection and competition between economic subjects.
To avoid a further tendency to derogate increasingly intricate and cumbersome decision-making processes (expanding recourse to "silence-consent", attribution of substitutive powers for the construction of major works, etc.), it is now also essential to get ahead of this thing together. By acting, for example, in such a way that the authoritativeness of planning institutions and instruments is guaranteed through decisive intervention in favour of more targeted public policies relying on linear, clearly selected technical-administrative devices.
In this perspective, it is very probable that the public apparatus is called to rebuild an operational capacity, which has been the object of repeated curtailing measures in the last decades (staff cuts, career freezes and transfers blocks, job insecurity and temporariness, reduced investment in training and technological innovation). It is also possible, however, that progress can finally be made towards an organic reform of the public procurement code, with the consequent rationalization of implementation processes and strengthening of social and territorial governance tools. With initiatives of this kind, it is likewise possible to finally counteract the gradual abandonment of the role of stimulus and guiding that has characterized the public debate for at least twenty years, but which, in light of the extraordinary commitment that will be necessary following the launch of *Next Generation EU*, seems to require a decisive change in course.
It should be pointed out that both policies for the correct use of the territory and reconstruction plans adopted in emergency situations can benefit equally from this drive towards de-bureaucratization, not only because, especially in Italy, these two different approaches to planning are used to coexisting due to widespread territorial contexts characterized by a high degree of natural risk. With a view to possible integration between these two different ideas of the urban-planning discipline, the tendency towards rationalization and the acceleration of decision-making processes may give rise to quite different responses. In the case of general urban planning we can expect, for example, a greater propensity to rely on new planning tools to renew the usual intervention strategies, with the goal of overcoming resistance to effectively accelerating decision-making processes. In the governance of territories hit by a natural catastrophe, this instead relates to favouring the discovery of certain clear synergies between measures intended to promote the reconstruction of the built heritage and a broader vision of policies that may lead to the rebirth of the entire region.
Behind the renewed need to strengthen planning, there is most likely an awareness of the failure of the *Minimum State* model, which played a hegemonic role throughout the long neo-liberal season (Wolff, 1991). The latter is a conviction that should have come to the fore much earlier, at the very least when the Great Recession that began in 2007 exposed the inability of market-regulation institutions to produce long-term views. Now, however, the foreseeable effects of the pandemic are finally forcing us to realize that the privatization and outsourcing of business activities that occurred in decades prior have considerably weakened the tools available to public administrations to respond to market crises (Mazzucato, 2020, p. 92).
The limits of this contribution do not allow for an investigation of the causes underlying the loss of competitiveness of the Italian system that has developed in recent decades, which is due especially to the inefficiency of the public administration, insufficient investment in human capital, and delays accumulated in the provision of the main infrastructure and technological equipment. If we limit ourselves to closely analysing the latter impediment, however, we cannot help but noting that the trigger of this important loss of efficiency in public action can probably be traced to the increased time needed to realize public works. The scientific literature usually traces this criticality is particularly tied to the 'crossing times' (Carlucci et al., 2019, p. 8), i.e. the time interval between a phase of realization of a sizeable public work and the next one

(design, tender, execution, testing). These times have a strong impact on the duration of the individual phases and depend on a variety of causes, although the weakness of the technical apparatus tends to be particularly important from a quantitative and qualitative point of view. According to an estimate made by the Agency for Territorial Cohesion, the crossing times measured throughout the implementation of public works constitute more than 54% of the entire duration of the implementation process, but the preliminary design phase alone is able to cover more than two thirds of crossing time (Agenzia per la Coesione Territoriale, 2018).

If we consider this pathological tendency in Italy to dilate the times needed to realize public works — which is five years for works with a value less than €300,000 and greater than 11 years for works worth more than €5 million (Carlucci et al., 2019, p. 24) — we should certainly not be surprised if Italy was, in 2019, in second-to-last place for spending capacity ahead of Croatia, with a percentage of Structural Funds usage at 30.7, and without recording any progress compared to the 2007–2013 period.

As a result of the delays accrued following the overlaps between the different programming phases — and the rush to use the available resources in order to achieve the expected spending targets and avoid the automatic cancellation of some programs — the use of the funds proved to constitute a real end «rather than representing a simple tool to achieve truly strategic objectives. The latter seem to have taken a back seat, along with the optimal use of resources and the measurement of results and real impacts» (Barca & Bruzzo, 2019).

Barring the adoption of further corrective measures, it is therefore inevitable that the spending capacity of EU resources will become a decisive factor in evaluating the foreseeable effects of the National Recovery and Resilience Plan (PNRR). It follows that Italy, which should receive a financial flow of about €248 billion between 2021 and 2026, will be subject to a formidable stress test.

Not only the marked acceleration of the implementation processes that will now be necessary, but also the experimental nature of some priority interventions and the supra-regional scale adopted for some major infrastructural works will require a new change in the balance between the public and private sectors. In a phase of intense perturbation such as this, even the relation between centre and periphery are probably destined to undergo a profound change, with particularly evident effects for the planning of interventions and for the configuration of the most important measures that will characterize the reconstruction of the country after the pandemic.

Especially in the case of territorial government, the need to innovate the matter which regulates the exercise of competing competencies between the State and the Regions may lead us to think of an intense and complex negotiation, if not even a comprehensive reform of Title V of the Italian Constitution. Nevertheless, the economic and social emergency in which we will have to operate in the coming years, and the need to respect the time constraints imposed by Brussels for the use of the extraordinary resources of the *Next Generation EU*, will probably suggest avoiding the danger of further extending the time required to search for a new institutional order and carry out the planned interventions.

Pending the redefinition — which is nevertheless necessary — of the inter-institutional relations that will have to preside over planning decisions, it is therefore convenient to hypothesize short- to medium-term measures with a prudent and incremental attitude that has already produced some preliminary results. Some examples include provisions adopted in the name of procedural simplification, the introduction of regulations favouring recourse to temporary uses, incentives for urban regeneration projects, and the recovery of abandoned buildings through the reduction, or even complete exemption, of the construction fee.

In an attempt to contain the paralysing effects generated by a model of "*defensive administration*" which, for fear of incurring censorship by the Court of Auditors, has led to the frequent renunciation of the exercise of power, the new legislative and regulatory interventions will probably seek to arouse a more marked administrative activism. This juridical device could very likely attempt to guarantee safe conduct for officials and administrators who, while perhaps falling into conduct that may abstractly involve objective liability, can only be convicted if the subjective nature of malicious intent is proven (Veronese, 2020).

It is worth underlining, however, that the initiatives promoted to accelerate implementation processes for major infrastructure works and increase the responsibility of the public apparatus are not without their problematic aspects. One example is the presence in the *Legislative Decree on simplification* of some dangerous steps backwards. The latter concern on the one hand the will to force the *Code of Public Procurements* and other European regulations to raise the threshold for the direct assignment of public services and works, and on the other hand the attempt to significantly broaden the field of applicability of the figure of Extraordinary Commissioner, in open contradiction to the need to entrust this new entity with realizing a limited and selected number of single initiatives or larger intervention programmes that really hold priority.

In order to correct such critical aspects, one could think about establishing one or more *Mission Units* to launch projects of strategic importance or activating working groups to promote experimental interventions in the field of urban regeneration. The desirable effect would be to return to the Ministries — starting with the Ministry of Infrastructure and Transport — a role that goes well beyond the 'rescue' of areas in crisis and rebuilds the resilient capacity of government institutions to adapt to and learn from emergency management.

As far as more specific urban-planning regulations are concerned, the simplification objective could be achieved by placing particular emphasis on redefining the procedure to approve urban planning instruments, streamlining procedures (especially for private initiatives) and strengthening the powers of the "Conferenza dei servizi" as a fundamental step in decision-making. The latter is a body that could allow even more significant cuts in bureaucratic times and should, above all, be convened not only for investigative purposes — contextually examining the various public interests involved in administrative procedures — but also with decision-making powers, to take decisions agreed upon by the various administrations, and replacing the current process of agreed acts, dispensations, agreements, or acts of consent, however they may be called.

4. The relationship between temporariness and continuity in strategic planning tools

As a result of a unique convergence in more general orientations, not only areas cyclically affected by calamitous phenomena, but also territories preparing to host the most significant interventions of the PNRR seem destined to undergo the next phase of intense transformations relying on the culture and tools of strategic planning. It is very likely that in having to pilot a change of such proportions without knowing precisely where it will end up, it will be necessary to consider of the need to rely on *transition management* devices. This is the case, for example, of the tools made available by Transition Management, a governance approach which aims to facilitate and accelerate even radical changes through a participatory process that relies on visioning practices, on the development of shared learning models and on generalized recourse to experimentation (Rotmans et al., 2001).

In its most successful application, this management of transformation processes brings together multiple points of view and various approaches in a 'transition arena' where the actors involved are asked to organize the problems and opportunities presented by the context to be changed. The basic objective of this governance model is to generate collective visions and objectives to inspire the creation of sustainable development scenarios to examine the possible effect of policies, which would then be tested, and their effectiveness and possible impact assessed.

Applying this paradigm first to the identification, and then to the study and classification of risks, the frequent failures recorded by the reconstruction interventions would tend to suggest a much more careful

and prudent exploration of the local context, thus proposing interaction with local actors and predict the role that these actors can play in the rebirth of the areas hardest hit by natural disasters.
As was recently pointed out (Annesi et al, 2017), this particular approach to the reconstruction of areas in the disaster zone may constitute an essential reference for empowering local communities and policy makers, which could act as the foundation for a request for new planning tools in the conviction that the latter will be able to contribute to defining shared medium and long-term scenarios in which all the main stakeholders will consider themselves directly involved.
It is very likely that, once tested in areas subject to the traumatic consequences of a high intensity earthquake, transition management will also make important contributions to dealing with problems more directly associated with climate change. In the shift from the current planning system to a different model of territorial governance, the intensification of the effects of climate change charges public policies with the task of securing settlement systems from dysfunctions due strictly to a decision-making process operating under evidently uncertain conditions.
Besides viewing transition management as a tool to guide local administrations towards a different destination, the move to a new planning model can naturally rediscover strategic governance to be an approach strictly functional for the need to promptly update the current regulatory framework on the local level. At the same time, the transition undertaken thus will have to allow the development of a long-term vision that will rebuild confidence in the future, securing territorial structures and settlement systems from risks associated with the presence of acute vulnerabilities (Talia, 2018, p. 61).
As we have mentioned several times, the expectations of strategic policies may represent an important bond between planning exercises growing out of emergency conditions and planning choices that intend to contribute more generally to territorial governance. In defining a point of connection between short and long-term solutions, decision-making processes referring to strategic aspects may constitute the most convincing response to the needs of territories affected by very quick, accentuated changes, whose overall development cannot be foreseen but which must nevertheless be guided.
In line with this basic approach, urban planning may definitively renounce a traditional conceptual and operational framework, which is based on the belief that the authority of the plan depends first and foremost on its ability to legitimize choices starting from a framework of rules and procedures, capable of ensuring a high degree of stability for the entire settlement system (Talia, 2020, p. 136). In claiming greater flexibility and adaptability for planning tools, a new period thus begins for territorial governance which is no longer a dependent variable of redistribution of wealth and economic incentives, but which is rather proposed as a strategic construct for a radical change of perspective.
A disciplinary shift of this type corresponds to the willingness to accept greater flexibility not only in managing uses in the existing city, but also in developing urban and territorial regeneration programmes for areas subject to the traumatic effects of natural and anthropic disasters. These areas must be allowed to convert their spaces and adapt their functions without necessarily calling into question the entire planning system still in operation.
In a period of transition characterized by uncertainties and risks such as the one we are currently experiencing, strategic planning — even with the limits and indeterminacy that still characterize it — can allow us to face the often radical criticism coming from the most diverse areas of the public sector without decreeing the substantial irrelevance of the urban plan.
This most likely implies the postponement of a radical reform of development policies and territorial governance to a now “pacified” phase, in which the complex transition that the contemporary society is going through - and which many commentators define as a sort of "interregnum" - will finally come to an end (Bauman & Mauro, 2015, p. 18). In the meantime, it will be useful to define new devices and procedures, even temporary ones, able to dictate flexible but transparent and highly performing rules from

the point of view of urban and landscape quality. In this perspective, the ability to mobilize new actors alongside the more traditional ones will be decisive, which together will contribute to the success of the experimentation of innovative procedures in the design and the management of sensitive territories and spaces to be allocated for collective use.

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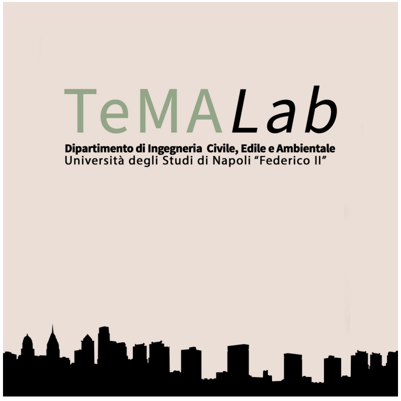

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Planning to prevent disasters

A short reflection on the correlation between ordinary planning and risk mitigation

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Abstract

The evolution of cities, whose pattern is all but regular, is sometimes marked by rare events that may disrupt the normal development. Throughout history, cities grow and shrink, flourish and perish, in a slow and somehow predictable way, but sometimes they suffer sudden and unexpected changes. Those breakages that profoundly modify their urban schemes and land-uses, their identity and their economic and social activities, transform them into entirely new cities or radically convert large portion of space.
Whatever the outcome of a disaster could be, although it may result in a pattern of positive development, we must prevent the loss of human lives, the suffering, the loss and damages that accompanies every catastrophe. The main task of human action must therefore be risk mitigation, bearing in mind that risk is always present and the resources to mitigate it are often scarce.
Without going into the detail of any particular event and with methodological intent, the paper will try to investigate how we can better understand risk and how planning may influence the mitigation of risk.

Keywords

Safety; Security; Planning in hazardous areas.

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1. Introduction

The evolution of cities, whose pattern is all but regular, is sometimes marked by rare events that may disrupt the normal development. Throughout history, cities grow and shrink, flourish and perish, in a slow and somehow predictable way, but sometimes they suffer sudden and unexpected changes. Those breakages that profoundly modify their urban schemes and land-uses, their identity and their economic and social activities, transform them into entirely new cities or radically convert large portion of space.

Earthquakes, volcanic eruptions, large landslides, forest fires, technological disasters and major industrial accidents, biological and chemical contamination and even terrorist acts are those catastrophes that may change the evolution patterns of urban settlements.

Disasters of similar intensity may have profoundly different impact on towns and cities. In some cases, the breakage is such that the places are rendered forever uninhabitable. A couple of examples, in very different times and conditions: Noto, in the southern-eastern Sicily, has been abandoned after the disruptive earthquake of 1693 and Prípiat has become an inanimate place after the nuclear disaster at Chernobyl in 1986 (Fig.1).

Noto, was in a geographical and morphological context of an hilly place that is (now) well known for amplificating seismic waves. Moreover, the urban design made of curved narrow streets is particularly vulnerable, as the buildings were non-seismic resistant.

The case of the radioactive fallout that makes places inhospitable has not been considered, due to the underestimation of the nuclear hazard and the inadequate security measures in Ukraine.

Noto (Italy), in the southern-eastern Sicily, has been abandoned after the disruptive earthquake of 1693.

Prípiat (Ukraine), was evacuated after the Chernobyl nuclear accident in 1986, when it had nearly 50,000 inhabitants.

Fig.1 The abandonment and the reconstruction can lead to completely different urban organisms

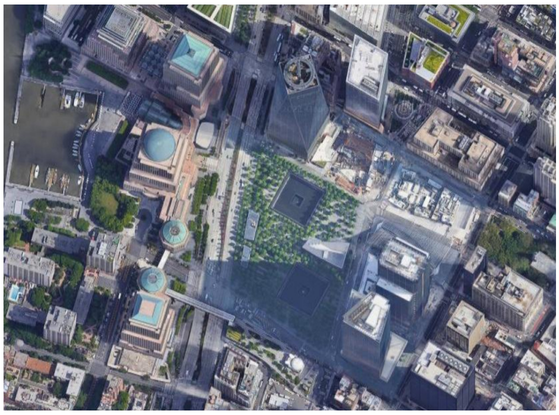
As a consequence of such a vast and profound destruction, those places have been abandoned, mainly because the on-site recovery was inconvenient or simply impossible.

It happened several times in history, to entire urban settlements, or part of them. The wound being sometimes so profound that the site affected by the disaster has been intentionally reported, becoming a memorial. That was the case after two completely different events, reason for as many great monuments: the expanse of concrete of Gibellina in Sicily and the Ground Zero memorial in New York.

In the first example, a new *filling* in the emptiness of nature to keep the memory of the previous dwelling. The second example: an unusual *empty space* in Manhattan's urban density, to underline the extent of the shock suffered and to respect the memory of the victims (see Fig.2).

One last introductive remark: many disasters have triggered processes of rebirth and new economic development. The crisis can bring progress, as in the crisis we learn from our mistakes and some great strategy may arise.

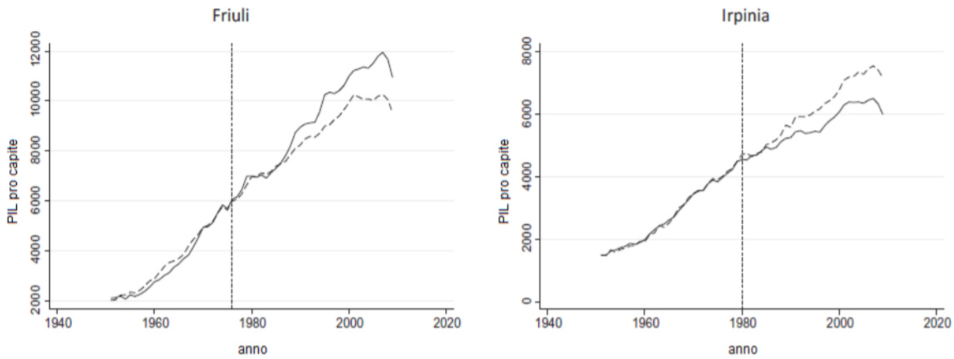
Gibellina was destroyed by an earthquake on January 15th, 1968. The *Cretto* from Alberto Burri recreates the place where the village stood.



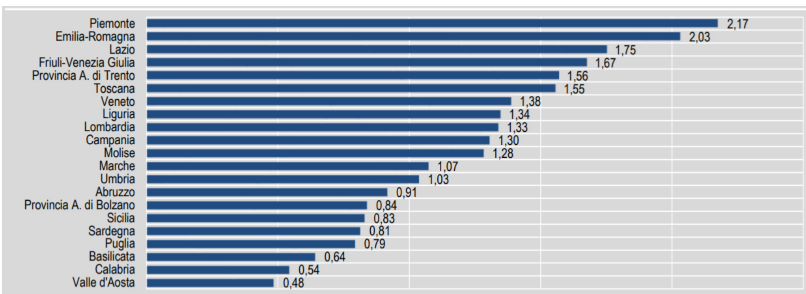
Ground Zero in downtown Manhattan: a terrorist attack destroyed the twin towers on September 11th, 2001

Fig.2 The expanse of concrete of Gibellina in Sicily and the Ground Zero memorial in New York

Noto (the "new" Noto) is one of the most fascinating dazzling Italian Baroque city, as the relocation was the opportunity for complete reconstruction. Regions as well may change their development patterns when strucked by disasters. In Italy, the emblematic case of Region Friuli certainly deserves attention. The buildings in the region have not only be rebuilt "as" and "where" they used to be, but the entire territory has also embarked on a new path of economic development, which has led it – among other things – to be today the fourth Italian region as of the percentage of R&D expenditure on GDP (see Fig.3).



Two Italian cases: Friuli (north of Italy) had a better development pattern after the earthquake of 1976, whereas Irpinia (south of Italy) had a worse one after the earthquake of 1980. (*The dot line shows the normal evolution of per-capita GDP, i.e. without the seismic event.* Source: Barone & Mocetti, 2014)



Friuli is the fourth region as of private R&D expenditure out of GDP (Source: ISTAT, 2018)

Fig.3 The resilience at work: how regions can react to catastrophes. Long term economic trends after earthquakes.

Whatever the outcome of a disaster could be, although it may result in a pattern of positive development, we must prevent the loss of human lives, the suffering, the loss and damages that accompanies every catastrophe. The main task of human action must therefore be risk mitigation, bearing in mind that risk is always present and the resources to mitigate it are often scarce.

Without going into the detail of any particular event and with methodological intent, the paper will try to investigate how we can better understand risk and how planning may influence the mitigation of risk.

2. Risk and the classification of disasters

What we call disaster, is a rare event that may cause harm and damages. Rare, as the frequency is low when compared to the normal functioning of a system. For example, an earthquake is extremely rare compared to the life of an urban settlement, as it may happen every few centuries, while a plane crash is rare if compared to the volume of traffic and the number of circulating aircrafts, even if several accidents may occur every year. Generally speaking, there are two ways of protecting against disasters. Prevention, so to reduce the probability of occurrence, the magnitude (when possible) and/or the amount of damages. Crisis intervention and recovery, also aimed to reduce damages, but with less efficacy and permanent losses (Røstum et al., 2008).
Rare events are most often concentrated in time and space, but their preparation can last significantly different and the area affected covers a wide range of possibilities.
Using the same examples, the concentration of forces that will be suddenly released in a seismic event will take decades or centuries to reach the critical point. As a consequence, the time to implement a safety plan can be long enough. Due to the high costs of prevention, the limited resources must be concentrated where the most dangerous event are expected. That's why the seismic zoning is the first and most important action to implement. A plane crash is a sudden break in the system, but scattered in time and space, as due to factors that can be instantaneous, such a malfunctioning or a distraction. Time and money must be devoted to design and implement a safety plan of the entire transportation system, with a particular attention to active safety measures. In order to mitigate risk, the well-known definition as a combination of three main elements is crucial. Risk is a non-linear function of hazard, vulnerability and exposure (Varnes, 1984). Through the management of those three fundamental components, most phenomena can be described and understood and the countermeasures implemented.
The word risk is commonly associated with concepts like uncertainty and loss or damage: the emphasis is more on the aspect of uncertainty, when the unpredictability of the event is pointed out; while it is more on the aspect of entity of damage, when the severity of the event is underlined.
Hazard (H), in the sense of possibility of damage (Volta, 1981), joins the two concepts in the same definition. The measurement of damage is substituted by the monitoring of two variables:

- vulnerability (V), or the propensity to damage as a consequence of a given event;
- exposure (E), or the quantity and value of goods (human beings and material goods) that are present in the area effected by the event.

So risk can be defined through the following function:

$$R = f\,[\,H\,(I);\; V\,(I,T);\; E\,(T)] \tag{1}$$

R = risk
I = intensity of the event;
T = typology of element potentially subject to disaster effects (population, goods, infrastructures, etc.);
H = f (I) = hazard, or the probability that a phenomenon of a fixed intensity (I) will occur in a defined period of time and in a given area;
V = f (I, T) = vulnerability, or the propensity to be damaged as a consequence of a fixed event (I) and in function of the typology of elements subject to hazard (T);
E = f (T) = quantity and value of the elements (T) subject to risk.

Hazard

The hazard can be defined by the intensity of the event, its link to the return time and the local conditions (called local hazard). The energy released by a seismic event, related to a given frequency; the volume of a landslide; the dangerous road conditions in the transport system can be assessed and mapped. Hazards can be concentrated (as in the technological disasters) or spread in wide areas (as in the case of meteorological phenomena).

Vulnerability

Different reactions to a given hazard reflect the conditions of the exposed elements (people and goods), but can be highly influenced by prediction, preventive measures, and emergency measures (the latter only when damages are reversible). The two main concepts of prediction and prevention are so introduced:

- a prediction oriented policy concentrates the efforts on studying predictive phenomena, in order to try to know before the time when the event will occur and its features;
- a prevention oriented policy, on the other side, try to plan the new pattern of the system and to prepare the targets exposed, in order to reduce vulnerability and then the risk itself.

Exposure

The third variable of risk function is the exposure: the risk increases when the quantity and value of targets increase. The maximum of exposure is determined by the presence of human beings, but also material goods are taken into account, such as factories, buildings, schools, hospitals, transportation and technological infrastructures, environmental goods, etc.

Urban habitat and its increasing complexity is the place chiefly exposed to risk, as it contains all of these functions. Nevertheless, the question of efficient exposure indicators remain prominent. The socio-economic level of population, the destination of buildings and the intensity of man presence are often chosen as possible indicators.

Preparedness can be better understood when the three components are isolated and the disasters are clustered in order to focus on the control of one or more components.

A proposal of disaster classification is shown in table 1 (Tira, 1997), where the events have been organised into three different categories.

- Physical events, where the cause is structurally natural (but the damage is not) and humans cannot determine the occurrence; in those cases, prevention activities must be concentrated on the reduction of vulnerability and exposure. Those activities are classified as passive ones, since no chance is given to reduce the magnitude of the event. The best examples are the seismic events: against them, passive safety measures are the building codes, as well as the rules for a seismic resistant plan (as in the examples illustrated in the next chapters);
- When passive safety is the only possible reaction, the marginal cost of interventions has to be calculated, in order to best locate scarce sconomic resources. The best solutions are those that realise a higher increase of safety with the same amount of money. The severity of building codes for seismic resistant structures is calculated assuming the building will be damaged by the event, but not collapsing, so saving lifes (but accepting damages to the structures and the goods);
- Physical events, where the cause is both natural and anthropic; in those cases, prevention activities must be concentrated on the reduction of vulnerability and exposure, but hazard can be also mitigated at a certain extent, at least by reducing its intensity. A typical example are floods, as a result of heavy rains (natural) and the impermeabilisation of soils (as a result of planning choices). Hydraulic models clearly show that the runoff is accelerated by impermeable soils, so that the river flooding will be more intense and rapid, so reducing also the possibility of application of emergency meaures.

The effect of the land use choice is a long process and the river basin as a whole may be interested. Safety measures can be active, as the revegetation or passive, i.e the strengthening of river embankments.

- Man-made events, where natural features may influence the results in harms and damages, but not the occurrence. The most important prevention activity is the reduction of hazards as depending from voluntary human activities. A typical example is a transportation accident, where the combination of three components influences the probability of resulting in harms and damages: the human behaviour, the technical failure (engine, breaks, etc.), the environment (the road layout, for example). In that case, safety measures can be either active (the intelligent braking systems or the lane control device) and passive, like the airbags.

In other words, we could cluster those disasters by the percentage of naturalness. That percentage is inversely proportional to the degree of voluntariness: the more an event is naturally based, the less it is voluntary, and the other way round. The terrorist acts are the extreme example of voluntary events as they are planned to cause harms and damages.

Also directly proportional to the voluntariness is the area of resentment of the events. Earthquakes are comparatively intense and concentrated (in space and time) when compared to ecological contaminations.

Type	Origin	Disaster
Seismic phenomena	PHYSICAL	* Earthquakes * Tsunami * Volcanic eruptions
Meteorological phenomena		* Hurricanes * Tornadoes * Severe fog episodes * Drought
Geological phenomena	*INTERMEDIATE*	* Floods * Mud or landslides * Avalanches * Epidemics
Ecological disasters (contamination)		* Forest fires * Chemical * Physical * Bacteriological * Radiological
Means of transportation accidents	MAN-MADE	* By air * By railway * By road * By sea
Technological disasters		* Barrage breakage * Bridge and structural collapses
Major industrial accidents		* Explosions * Fires
Terrorists acts		* Biological and chemical contamination * Mine disasters

Tab.1 A proposal of classification of peacetime disasters (Tira, 1997)

Indeed, any physical event is influenced – to a certain extent - by human actions: for example, the effects of an earthquake are strongly linked to the social organisation, the Institutional framework, etc.). At the same time, the consequences of any man-made disaster can be worsened by natural conditions: for example, the effects of traffic accident are highly influenced by the weather conditions.

In the English wording there are some differences between the words "safety" and "security". The term "safety" is used for protection against unintended incidents (natural or intermediate), while the word "security" is often used to describe the reaction against deliberate incidents (man-made).

We will define as "unsafe" that place that is prone to physical hazards, those due to natural characters of human habitat (such as earthquakes, hurricanes, volcanic eruptions). An "unsecure" place is that subject to the man-made hazards, caused by anthropic modifications of the environment (i.e. technological hazards, such as major industrial accidents or oil spills; environmental hazards, such as chemical contamination or water pollution; traffic conflicts and accidents; riots and terrorist acts).

3. Planning as an opportunity for rebirth

The introduction outlined some extreme consequences of disasters. Those are situations that have led to new localisation choices, either total or partial.

Dealing with cities, however, the most interesting examples and those where recovering *in situ* replaced the living conditions as similar as possible to those before the disastrous event. The competitiveness and vastness of human settlements is such that it would be vain to think of new locations to escape the threats arising from natural or anthropic phenomena. It is therefore in the reconstruction that the most current challenges and problems are found and where the circularity of figure 5 finds its most challenging expression.

Many examples of *in situ* reconstruction of cities (generally larger and more complex) can be found in history, recovered and adapted to the new disaster protection needs that had affected them. For example, the reconstruction plan of Catania after the earthquake of 1693 and the new Lisbon after the earthquake of 1755 (Fig.4).

Catania, plan from A. Vacca (1960). The radically new town scheme is evident overall in the road network

The new plan of Lisbon according to Eugénio dos Santos and Carvalho, and Carlos Mardel (Source: plan of the town by J. Pinto Ribeiro, Gabinete de Estudos Olisiponenses, Lisbon)

Fig.4 The resilience at work: how cities can react to catastrophes

Catania has been re-planned in order to resist better to new possible events. The dimension of the town was too big to be entirely moved in another place, so the project was entrusted to a team of experts, formed by well-known architects such as Sebastiano Ittar, Stefano Battaglia and Giovanni Battista Vaccarini. The city was redesigned according to practical logics and ideals of illuminism, typical of the European context of the time. That is maybe one of the first examples of seismic resistant plan (together with Lisbon after the earthquake of 1755). The project involved a new road layout of the city, much more schematic and practical, accompanied by the widening of the streets and the creation of open spaces that are still signalled today as safe recovery places in case of emergency. The reconstruction has become a symbol of economic recovery in the modern history of Sicily as after the first period of emergency, the extensive construction activity carried out in the affected area reactivated its entire production cycle (L. Dufour and H. Raymond, 1994).

Lisbon was rebuilt by Sebastião José de Carvalho and Mello, Marquis of Pombal. Between 1756 and 1777, Pombal promoted the reconstruction of half the city. He completed his work by erecting, instead of one of the cornerstones of eighteenth-century urban planning, "the royal square", the Piazza del Commercio, whose name explains what was the result of the reconstruction of one of the capitals of Europe. The reconstruction was carried out on the basis of the proposals of an 80-year-old military engineer, Manuel de Maia, who followed three different directions, the same that in the face of every catastrophe urban planners are obliged to propose: the reconstruction of the city as it was; a radical reform that would allow it to be modernised; the construction of a new capital. The choice was to radically renovate the city by reforming its ancient plant, as the logic and intelligence of an administrator of Pombal's stature and the interests he represented imposed (Dal Co, 2012).

Preparedness is the only wise approach, and planning is a typical preventive action.

Describing the space development when facing a disaster as a circle, crisis intervention has to be seen only as the pre-condition for the correct prevention and preparedness activities. The chain (Smith, 1998) consists of the following stages which together make-up the so called disaster (or risk) management cycle:

- pre-disaster or preventive planning covering activities which range from the construction of defensive engineering works to land use planning and elaboration of evacuation plans;
- preparedness reflecting alertness immediately before the onset of a hazard, when feasible;
- response referring to reaction activities immediately before and after and (emergency) relief operations;
- recovery and reconstruction, concerning the long-term activities destined to return an area to "normality" after severe devastation.

The so-called cycle risk management approach (Swiss Federal Office for Civil Protection, 2008; Fig.5) has been quoted several times as a clear taxonomy for all step of risk management (see among others: Røstum et al., 2008).

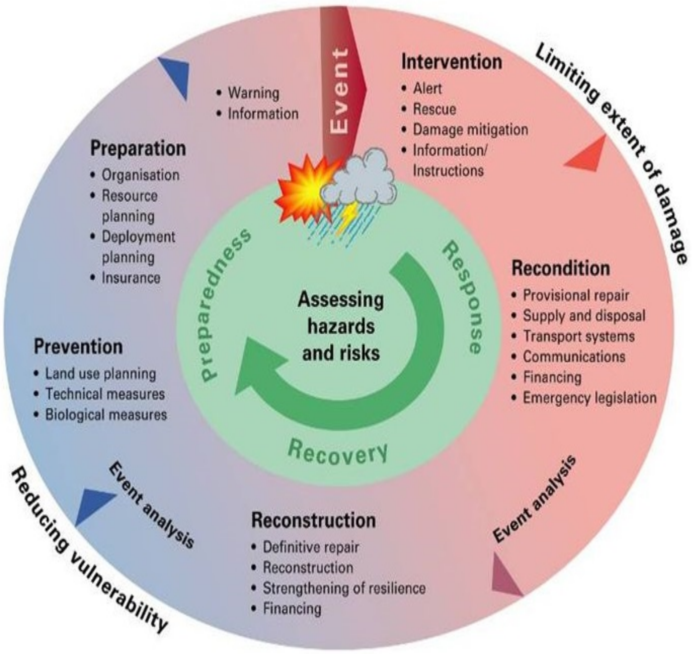


Fig.5 Cycle risk management (Source: Swiss Federal Office for Civil Protection, 2008)

Land use planning is in the prevention part of the circle, and the sector of vulnerability reduction. The value of danger is provided either by specific studies or regulations, whereas the values of vulnerability and exposure are to be defined, considering the complexity of urban systems.

Exposure depends on the presence of goods and people in the hazardous area, and can be assessed as the presence of average residents per area or the destination of buildings.

Spatial planning of risk areas must therefore take into account that prevention must be entrusted mainly to ordinary rather than non-extraordinary instruments.

The reliability, safety and security of urban systems must be an inalienable objective of ordinary planning activity. The duty of sound planning is to provide the direction for growth that guarantees the maintenance of a level of functionality in case of crisis, the so-called resilience, whereas the duty of correct emergency planning is to ensure, as quickly as possible, the restoration of the (previous) conditions essential to urban functioning. Nevertheless, any emergency action can be a first step towards the following preventive activity!

Modern planning legislation contains at least a couple of very relevant contributes to mitigate risk through the planning process: the geological survey, as a compulsory content to add at the many prescribed for the design of urban schemes in risk sites and the strategic environmental assessment (SEA), as a compulsory evalutation procedure, introduced by the EU Directive 2001/42.

The geological survey is relevant to reduce the impact of land government with regards to the geomorphological features and the previously defined natural and intermediate disasters (see Tab.1).

The SEA is a broader environmental evaluation of the effects of a plan, assessing the effects on the full environmental matrix.

Both geological survey and SEA present weak point. The geological survey influences planning costs, being a complex and long procedure. So, it is often reduced to some parts of the plan, where an a priori development strategy is going to be implemented.

The SEA, also costly and long, is often reduced to a qualitative analysis of the major impacts, often neglecting the probability of occurrence of rare events, changing the scenario.

Planning frameworks are quite appropriate, practice is far from being, also still mainly influenced by the socioeconomics demands arising from the citizens.

4. The socially acceptable risk level

Planning processes are extensively in-depth processes, which deserve to be examined more widely. The two reconstructions of Catania and Lisbon are due to totalitarian regimes, which have more easily in history been able to reorganize urban spaces quickly, but to the detriment of the indispensable democratic processes that no one would give up anymore, not even in the face of greater security (what about the debate about the restrictive measures imposed by the COVID-19 pandemic?).

The increased need for transparency of programming and planning choices, due to the presence of various and clashing goals, determines the problem of allocating the public finite resources.

While risk is measurable, the reaction to threats can be very different according to personal culture, age, preparedness, and health conditions.

For example, the youngers are more unconscious of the effects of hazardous activities and situations, whereas the elderly may have a distorted perception of the most dangerous activities. For example, old population living in wealthy European urban environment is much more scared by personal attacks, than from car accidents. The evidence shows that traffic casualties are more and more severe than muggings.

Worth mentioning also a couple of other elements influencing risk perception.

An overestimation is very common when the target exposed feels like being without control on the situation. In the field of transportation, that clearly explains how air transportation is often perceived as a more dangerous means of transportation when compared to car.

Secondly, an underestimation of the consequences of disasters is recorded when the events are scattered (diffuse) in time and space. Again, that is a reason why road casualties (that are many more) have a smaller impact on public opinion when compared to the casualties resulting from a plane crash (rare but concentrated in time and space).

Conflicts and then risks are an unavoidable dimension of urban life.

As a consequence, risk management policies and the planning choices call for a coherent determination of the acceptable level of risk, both when compared to benefits coming from human activities and to the available resources to mitigate risks themselves.

The problem of making explicit the implicit level of socially acceptable risk has been addressed extensively in the literature. With reference to Starr (1969), we may quote at least three relevant alternative approaches.

a) Risk balance: the approach assumes that a level of risk higher than zero is socially acceptable and seeks to determine this by comparison with known cases, such as risks arising from activities similar to those charged. The evidence shows that people accepts voluntary risks much more than those deriving from involuntary events;
b) Cost-effectiveness balance: this approach measures the reduction of the risk obtained for each euro spent on security measures. The acceptable level of risk is that a further increase in expenditure generates such a small reduction in risk that it is now considered insignificant. In this way, different types of hazards can be compared and, once the resources for risk reduction have been allocated, it may be decided to invest them in those that have a better cost-effectiveness ratio. Please note, however, that not all security policies have a "measurable" cost;
c) Cost-benefit balance: the approach assumes that a level of risk greater than zero is socially acceptable if other objectives are to be achieved. The acceptable level is determined by balancing the benefits of an activity with the risks it entails. For example, balancing the localised benefits (less distance, lower transport costs) of some production facilities in hazardous areas: the greater the difference between the benefits of planting in such areas and safer but more disadvantageous areas, the higher the acceptable level of risk. As a result, plants with the greatest localised constraints, i.e. less transferability, are those with which the highest tolerated level of risk should be associated.

However, accident protection behaviour is markedly different according to the social weight and not just the individual weight attributed to them: in general, there is less attention paid to events that affect them more dispersedly (or at least apparently so) and greater attention to events concentrated in space and time.

This could result from an objective greater difficulty in protecting against the widespread phenomenon, but it follows above all from the different level of acceptability of the risk itself. Proof of this is the fact that even for road accidents, for example, a typical dispersed event, non-random concentrations (the so-called black spots) occur, but awareness of this characteristic of the phenomenon is very little widespread. Only recent acquisitions and specific research highlight the recurrence of road accidents in typical and recognizable urban situations. The level of social acceptability of the risk is a consequence of these brief differences, but at the same time partly determines them in cultural stratification and collective imagination.

5. Some conclusions

In drawing up some attempts at conclusion and, above all, trying to outline some perspective, we may take up a couple of questions: why does town planning, which has so much to say about issues such as emergency planning and risk, fail to play the role it deserves? Is the problem with the "speakers" or the "listeners"?

There are many possible answers.

First of all, the complexity. The ideal, static models that correspond to archetypes with which we try to describe urban realities actually correspond to a schematization of a reality that evolves and transforms according to probabilistic logics.

We know the main events that can occur with reasonable probability, but we are unable to reproduce on paper, except with subsequent scenarios, the outcomes of these events.

In other words, urban planning acts with static planning acts, superimposed on a rapidly changing reality.

A second element is the scarce diffusion of the concept of prevention: it is little understood in Italian society, little practiced in general, and this is reflected in the "listeners", in those who govern at all levels. We live in a "fragile" territory, but at the same time we are used to a generous nature, which has made us forget the need for a balance between anthropic development and environmental protection. Furthermore, we are immersed in a pervasive faith in technology that makes us believe that any human undertaking and any compensatory solution are possible.

The basic reason why prevention is not a common value in Italian society, however, is the lack of attention to the common goods. The awareness of belonging to a *unicum* is much weaker when compared to our interest on private space.
A third level of problem concerns the formation of political consensus. In the process of designing urban plans, the administrations dedicate an infinite amount of time to the evaluation of small interests, often losing sight of the strategic design. With this approach it is practically impossible to prevent risks, as prevention implies the ability of strategic reasoning and a medium-long horizon for choices. Many choices of prevention could be unpopular, they do not pay in the electoral arena, as they may limit private property, in view of the common utility to which it is also called.
A fourth element, which instead concerns the "speakers" and therefore the discipline, is the need to investigate the aspects of the interaction between physical elements and urban structures. Without serious consideration of these matters and design abilities, traditional planning processes are blunt weapons, if not the very cause of the problem that one would like to solve.
In other words, forcing the reasoning a little, we are asked to determine the response spectrum of the territory to external input. This means measuring the contribution and effect of impacting actions on the different components of urban systems and decode the response of each of them to the various inputs (Galderisi, 2020).
So, a change of attitude is needed: to get out of the logic of the emergency, we could say that we should transpose the emergency into the administrative and decision-making processes and raise a civic awareness of the value of the common goods.

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Fig.3: Barone & Mocetti, 2014 and ISTAT, 2018

Fig.5: Swiss Federal Office for Civil Protection, 2008

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